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STORMWATER QUALITY MODELING

FOR AUSTIN CREEKS

City of Austin

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FOR AUSTIN CREEKS

Prepared by
Watershed Management Division

City of Austin
Department of Public Works
November 1984

Richard L. Ridings, P.E.

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Date

STORMWATER QUALITY MODELING STUDY

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Engineering Report

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Executive Summary

This study is one of several modeling studies which were initiated to compile and analyze the hydrologic and water quality data that are available from various monitoring programs. The objective of this study was to develop mathematical models which describe stormwater runoff and pollutant load for Austin creeks. The watersheds of the creeks have varying degrees of multiple land use development. The creeks included in this study are Barton, Bull, Shoal, Boggy, Bear, Walnut, Waller, and Williamson. The pollutant parameters included are fecal coliform (FC), total suspended solid (TSS), Nitrate (NO_3), Ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), Total Phosphorous (TP), Total Dissolved Solid (TDS), Biological Oxygen Demand (BOD_5), and Total Organic Carbon (TOC). Data for this study were obtained mainly from the USGS/City of Austin Cooperative Monitoring Program.

Rainfall to runoff to pollutant load relationships were developed for various pollutant parameters in Bull, Boggy, Shoal, and Barton Creeks, using monitoring data from significant storms occurring between 1976 and 1982. For each watershed the runoff volume versus rainfall depth and runoff pollutant load versus runoff volume relationships were fitted to linear or geometric equations using the least square methods. In general, variability measures indicated that these equations provided a good representation of the actual situation. Using the equations developed in this study and available rainfall data, the runoff volume, and in turn the pollutant loads, were computed for all rainstorms within a specific historical period. The monthly pollutant load was estimated by summing the loads generated from the individual storms. The estimated loads for one-month periods were averaged over time to yield pollutant load for a particular calendar month. The sum over all twelve (12) months of pollutant loads for a particular pollutant parameter was used to produce the predicted annual load for each watershed.

It was found that in general, both the rainfall runoff and pollutant load increased with increasing percent impervious cover, an indication of urban development. Thus, as impervious cover increased, a given rainfall depth produced greater runoff depth, and in turn, greater pollutant load. The runoff and pollutant load to impervious relationships for storm-event conditions were developed. Pollutant concentrations also increased with imperviousness in most cases. Baseline water quality conditions were evaluated for Bull, Barton, Shoal, Boggy, Bear, Walnut and Williamson Creeks. The storm-event and baseline average pollutant concentrations for the study watersheds are presented.

In summary, the water quality of Austin area creeks depends on the quantity of stormwater runoff, which in turn depends on percent impervious cover. As percent impervious cover increases, pollutant load increases for a given rainfall. The effect generally accelerates as the rainfall depth of the storm event increases. Monthly and annual pollutant loads predicted for Austin area creeks may be useful for planning and design purposes.

This report supercedes the interim report on this subject completed January 1983.

10W01/4/ex sum

STORMWATER QUALITY MODELING STUDY FOR AUSTIN CREEKS

INTRODUCTION

This stormwater quality modeling study was conducted as part of the urban watershed management program for the Austin metropolitan area. The purpose of the study is to assess the current water quality conditions in Austin creeks and to determine the impact of urbanization on both the quality and quantity of stormwater runoff. The stormwater runoff pollutant loadings for the Barton, Bull, Boggy, and Shoal Creek watersheds were studied. These watersheds have multiple-land uses with various degrees of urbanization. The baseline water quality conditions of these and other creeks--Bear, Walnut and Williamson--were also studied. Data used in the study were mainly obtained from the United States Geological Survey/City of Austin cooperative monitoring study.[1] This report supercedes the interim report on this subject completed January 1983.

The cooperative monitoring program between USGS and the City of Austin was begun in October 1974. The USGS performs periodic water quality sampling for various Austin area creeks and lakes, and has established a network of streamflow and rainfall gauges for storm analysis. The program has been expanded to include groundwater and storm-event water quality sampling and to measure the effectiveness of detention/sedimentation basin. The City of Austin's Nationwide Urban Runoff Program (NURP)[2] was designed to develop a local data base on stormwater runoff pollutant loads and to document their effects. The NURP monitoring program was conducted during 1981 for three test watersheds representing different degrees of residential development. Some other water quality monitoring programs in the Austin area include lake water sampling by the City of Austin Health Department and Water and Wastewater Department, and lake and groundwater surveys by the Texas Department of Water Resources. In order to satisfy the needs which were not covered by the NURP program, the City of Austin has implemented the Stormwater Monitoring Program.[3] This program will obtain water quality data on runoff from nine (9) watersheds with specific land uses and will determine the efficiencies of various structural stormwater controls for removing pollutants.

In connection with the various monitoring programs, the City Public Works Department has initiated modeling studies to compile and analyze the available water quality and hydrologic data. This report is part of the modeling studies.

SCOPE OF STUDY

The major streams in the Austin area include the Colorado River and its tributaries. The Colorado River bisects the City of Austin and is impounded in two riverine reservoirs, Lake Austin and Town Lake within the City of Austin. Lake Austin is a popular recreational area, as well as the principal source of drinking water for the City's populace. The major tributary of Lake Austin is Bull Creek. This watershed is currently mostly undeveloped, but is developing very rapidly. The Town Lake watershed consists of much of the urban core area and the lake serves as an auxiliary drinking water source and recreational area. The lake receives substantial quantities of urban stormwater runoff from primarily high-density residential and commercial areas. Shoal, Waller, and Barton Creeks are the main tributaries of Town Lake. Several major creeks enter the Colorado River below Town Lake Dam, including Boggy, Walnut, and Onion Creeks. Barton Creek, along with parts of Onion Creek and its tributaries Williamson, Bear, and Slaughter Creeks are in the Edwards Aquifer Recharge Zone (the locations of these watersheds are indicated in Figure 20).

Because there are no significant point-source pollution discharges into either Lake Austin or Town Lake, stormwater runoff pollutant load is considered to be the principal contributing factor impacting the water quality of Austin area creeks and thus the lakes. Objectives of this study are as follows:

1) To develop regression empirical relationships for storm rainfall to runoff to pollutant load for several creeks representing various levels of urban development

2) To estimate runoff pollutant loading rate, i.e., load per month/year per unit watershed area, for the above mentioned creeks, and

3) To determine baseline water quality conditions for several creeks representing various levels of development

PREVIOUS STUDIES

In 1976, Espey, Huston and Associates[4] conducted a study for the City of Austin to evaluate the effect of land development on the quantity and quality of stormwater runoff into Lake Austin. The study used empirical equations to determine stormwater runoff quantity and quality for a specified storm under different development plans. The study concluded that the rate and volume of surface runoff, the pollutant concentrations, and total loading in surface runoff and in Lake Austin will be increased by urban development unless control measures are implemented. The empirical equations were based on very limited data, since there was practically no runoff and water quality data available for the Lake Austin watershed in 1976. In June 1978, Espey, Huston and Associates[5] presented the results of a stormwater runoff sampling program for the Austin Intensive Planning Area. The program included monitoring of two storm events in November 1977 for six stormwater sampling sites representing various land uses along the Colorado River in the Town Lake watershed. They estimated the stormwater runoff pollutant loadings that would result from a storm event for most of the Austin area watersheds and for four different land uses. The estimation, however, could not be generalized because of limited data. In June 1979, Espey, Huston and Associates[6] prepared a study for the City to determine the effect of urbanization on the Barton Creek watershed. The surface water and groundwater quality, spring discharge, and ecology for existing conditions and two additional development scenarios were evaluated. The water quality evaluation was based on the comparison of storm event oriented data between an urbanized and an undeveloped watershed. Two storm events were monitored for the 161.7 acre urbanized watershed and one for the 321.4 acre undeveloped watershed. The results of the sampling indicated that the water quality concentrations are generally higher for urbanized watersheds.

An urban stormwater sampling and lake survey study was conducted by Engineering Science[2] for the City of Austin NURP project. Three stormwater sites with specific land uses were monitored. The three sites were classified as moderate density residential use, low density residential use, and undeveloped land, with impervious covers of 39, 21 and 3 percent respectively. Results of the sampling study show that the moderate density residential use produces more runoff and higher runoff pollutant loads than the low-density residential use. Multiple regression equations for estimating runoff pollutant concentrations for two test watersheds were developed.

The study, however, was limited in some areas, due to funding constraints and unexpected equipment malfunctions. Sufficient data were not collected from the Turkey Creek site, the undeveloped watershed. The pollutant loading at Turkey Creek during storms was not evaluated, since no corresponding flow measurements were made. The storm loading data for the other two test watersheds were obtained for storms with runoff depths of about 0.002 to 0.07 inch. Therefore, the effect of runoff volume on the pollutant loading were not fully quantified for the normal range of runoff volumes occurring in the Austin area.

DESCRIPTION OF THE STUDY AREAS

The present study used data obtained from the USGS/City of Austin cooperative monitoring program. The Austin area streams included in this study are Bull, Barton, Shoal, Boggy, Waller, Walnut, Bear and Williamson Creeks. Analyses were made of the water quality and hydrologic data collected at several USGS gauging stations. These stations and the drainage area above the stations were listed in Table 1. (All figures and tables are presented in the appendix.) The storm loading data of the NURP project were also analyzed using the methods of the study.

Bull Creek is a major tributary of Lake Austin. The watershed has a drainage area of about 31 square miles with 12.5% impervious cover, which contains some of the most beautiful landscapes around Austin. Although it is not yet urbanized, the watershed is subject to very rapid development. About 25 percent of the watershed area is made up of slopes of 15 percent or greater. Because of its steep slopes, there is a high potential for the increase of runoff and erosion following development. The development of the watershed is subject to the City of Austin's Lake Austin Ordinance[7], which was implemented in 1978 for the protection of the water quality of Lake Austin.

Barton Creek is the largest of all the creeks that flow into Town Lake. The entire watershed of about 120 square miles with 8% impervious cover is in the Edwards Aquifer Contributing Zone and the lower portion of the creek is in the recharge zone of the Aquifer, which provides some water supply and a great recreational resource for Austin area residents. Part of the stream bed near Town Lake forms Barton Springs, the famous natural swimming pool in Austin. Many citizens believe that the runoff, erosion, and pollution resulting from poorly planned development could adversely impact Barton Creek and Barton Springs. To help avoid this, the City implemented an ordinance[8] in April 1980 providing standards for the development of the watershed.

The Shoal Creek watershed is entirely within the Austin City limits, and has a drainage area of about 13 square miles with 47% impervious cover. The watershed of the creek is almost fully developed. This creek has heavy pollutant loadings.

Boggy Creek is also a highly urbanized stream. It enters the Colorado River below Longhorn Dam (Town Lake). The creek has a total drainage area of about 14 square miles with 40% impervious cover. Although the watershed is flatter and less developed than Shoal Creek, Boggy Creek has regular flooding and similar water quality problems.

All development is subject to the 1974 Creek Ordinance[9], which was implemented to protect the water resources of the City and to assure that development is consistent with wise flood plain management practices. Specific ordinances designed to protect the quality of water in Austin, such as the Lake Austin, Barton Creek, Williamson Creek, Bear Creek, Slaughter Creek, and Onion Creek ordinances were approved by the City Council, beginning in 1978.

The watershed development can be characterized by the land use of the watershed. Land use distributions for several Austin creek watersheds were estimated and are given in Table 2. The estimates were developed from the City of Austin Planning Department data.[10] Each land use is associated with a percentage of impervious cover as presented by the Hydroscience study[11]. The degree of development or urbanization is then represented by the weighted percentage of the impervious cover. As a refinement, the watersheds' imperviousness were also measured by the grid method using watershed aerial maps. The measurements are generally compatible with the initial estimates.

MODELING METHODOLOGY

For background on the model formulated herein, one should refer to the studies of Grace and Eagleson[12], Bedient et all[13], and Denver Regional Council of Government[14]. Grace and Eagleson developed a probability model for generating synthetic sequences of short-time-interval rainfall depths. The proposed model utilized probability distributions fitted to the historical data values for the time between storms, storm duration, and storm rainfall depth. Bedient, et al studied the Brays Bayou watershed in Houston, Texas. Bedient derived linear pollutant load versus storm runoff relationships for several water quality parameters for three urbanized areas, ranging from 4.41 to 86.3 square miles. The Denver NURP study presented equations for predicting runoff from rainfall for a given percent imperviousness, and equations relating pollutant loads to total runoff. In this study it is proposed to use a nomograph to relate those variables for specific development sites.

Regression models for continuous simulation of stormwater quality have been developed in this study. The models were developed by fitting rainfall, runoff, and pollutant data to linear or geometric relationships using the least square method. The choice of the fitting, i.e., the type of the relationship, depends on which has better correlation and/or regression. The significance of correlation or regression is determined by the Student-t test[15] of the value of correlation coefficient or regression coefficient. The following procedure described the model formulation and the simulation being proposed.

1) The historical daily rainfall data for a watershed is reviewed. The rainfall data consist of a sequence of rainstorms which are separated by dry periods. A rainfall storm is defined as one day or a number of consecutive days of rainfall. One day is assumed to be the minimum dry period. The number of dry days between rainstorms is assumed to be a random variable. A rainfall depth of less than 0.05 inch is assumed as no rainfall. The rainfall depth of a storm is the cumulative depth of all consecutive days of rainfall for an individual storm. The storm runoff is the streamflow generated from the storm.

2. Available data of storm runoff depth versus rainfall depth for a watershed is fitted to linear or geometric equations. In order to make the model physically reliable, the fitting of a linear equation is constrained to end at the origin, i.e., no rainfall-no runoff. The watershed antecedent soil moisture condition should be considered in the equation if the impervious cover in the watershed is insignificant.

3. Available data of storm runoff pollutant loading versus storm runoff depth is fitted to linear or geometric equations for each water quality parameter. In order to make the model physically reliable, the fitting of a linear equation is constrained to end at the origin.

4. It is also assumed that the variables in a linear regression relationship are normally distributed. Therefore, the statistical examinations such as F-test[15] and Student-t test can be conducted in order to determine the significance of the relationship.

5. For any storm within the span of data used to generate the models, the storm runoff and pollutant load can be estimated using the equation developed in Steps 3 and 4. The monthly or annual total pollutant loading can be obtained by summing the pollutant loads from storms occurring during each month or year.

6. For modeling purposes, the degree of watershed development is represented by the amount of imperviousness in the watershed. For a

watershed of specific imperviousness the amount of storm runoff and its associated pollutant load can be estimated from given rainfall amount as described in the last paragraphs. Therefore, curves can be generated for pollutant load versus impervious cover.

7. In the probabilistic case, all the hydrologic and water quality parameters are assumed to be random variables and have specific probability distributions. The time between rainstorms (number of dry days) and the storm duration are independent variables which can be fitted to univariate probability distributions. The rainfall depth is either independent from all other variables or dependent on the duration of the storm. In the latter case, the regression equation of rainfall depth on storm duration can be developed. Similarly, the pollutant loads depend on runoff depth, and in turn, depend on rainfall depth, and the regression equations of pollutant load on runoff and runoff on rainfall can be developed. A random component[16] which is proportional to the standard error of estimate should be included in the regression equations. In forecasting the watershed pollutant loading rate, such as load per unit area per year, a series of rain storms for the one-year period can be generated by simulation using the probability distributions of time between storms, storm duration, and rainfall depth. The storm runoff and pollutant load for each storm can be computed from the regression equations described above. The pollutant load for the one-year period is the sum of the loads for the individual storms. The simulation can be repeated for several years. The pollutant load for each year is computed. The mean annual pollutant load is the average of the loads for the individual years.

MODELING RESULTS

The daily rainfall data of 1976-1982 for Bull, Barton, Shoal and Boggy Creeks were examined. The number of dry days between storms and the storm rainfall depth of each storm for this period for each of the study watersheds were determined from the recorded data. The data of number of dry days and storm rainfall depth were divided into bimonthly groups and the grouped data were fitted to either normal or log-normal probability distributions, depending on which gave better fit. The arithmetic or geometric means of these data are presented in Tables 3-6.

The data of storm runoff volume and storm runoff pollutant concentration for each watershed were examined. The sampling distributions of the two variables or their logarithmic transformations are normal distributions. The runoff pollutant load is the product of storm runoff volume and average storm runoff pollutant concentration and therefore it has the same type of distribution, i.e., normal distribution. This satisfies the assumption of normality of variables in testing the regression relationships.

The storm rainfall-runoff relationships and the average runoff coefficients (ratio of runoff amount to rainfall amount) for several watersheds were developed. The Student-t tests for the correlations and regression coefficients indicate that the relationships are significant. The average runoff coefficients were either the arithmetic or geometric means of the coefficients for individual storms, depending on fit of observed data to normal or log-normal distribution. The fittings of the linear relationships were adjusted to end at the origin. Based on the Student-t test, the adjusted relationships are significant. The slope of this linear equation represents the average runoff coefficient. The runoff coefficients for several watersheds are listed in Table 7.

Data of storm pollutant load versus storm runoff for the four watersheds were fitted to linear or geometric equations as shown in Tables 8-11. The choice of the fitting depends on which has better correlation. The fittings of the linear relationship were adjusted to end at the origin as shown in Figures 1-8. The resulted fittings are generally significant as evidenced by the Student-t tests. The regressions for a few cases, however, are not significant as indicated in the footnotes of Tables 8-11. The average monthly and yearly pollutant loads. for each of the four watersheds were computed using the predictive equations. The predicted pollutant loads for one month periods were averaged over time (1976-1982) to yield predicted pollutant loads for a particular calendar month. The sum over all 12 months of pollutant loads for a particular pollutant parameter produces the predicted annual load for that individual watershed (Tables 14-17). The loading characteristics of the NURP watersheds were also analyzed using the described model (Tables 12-13). It should be noted, however, that the NURP loading data should not be compared with that of the creek watersheds. The NURP watersheds are specific residential developments which have much smaller drainage areas and different drainage patterns as compared to the large, multiple land use creek watersheds.

The land use and the amount of impervious cover were determined for the study watersheds as shown in Table 2. The imperviousness was correlated with the runoff coefficients as shown in Figure 9. The data presented in Tables 2 and 7 was used to generate this correlation. For given rainfall depths, the linear relationships between storm pollutant load and imperviousness for each described pollutant parameter are developed as shown in Figures 10-15. The information of these figures are summarized in Table 18. The storm event loading equations presented in Tables 8-11 and the impervious cover values in Table 2 were used as the basis for these linear correlations. The Student-t tests indicate that the correlations are significant.

The average storm runoff pollutant concentration is estimated as the geometric mean of the flow-weighted average concentrations of the individual storms. The slope of a linear relationship of load versus runoff (Figure 1-8) also represents the average concentration. The storm pollutant concentrations for each watershed are listed in Table 19.

The comparisons of baseline water quality conditions for the studied watersheds are similar to that of the storm-event data. The Shoal and Boggy Creek pollutant concentrations are generally higher than that of Bull and Barton Creeks. Seasonal variations are significant for some of the pollutants. The baseline pollutant concentrations are best described by either normal or log-normal probability distributions. The baseline water quality conditions are represented by either the arithmetic or geometric mean of the pollutant concentrations. The results of this analysis for seven creeks are given in Tables 20 through 28. The pollutant concentrations are correlated with watershed conditions or imperviousness as shown in Figures 16-21. The average baseline concentration values for Bull, Barton, Shoal, Boggy, Bear, Walnut, and Williamson Creeks presented in Tables 20-28 and the impervious cover values in Table 2, were used as the basis for these linear and non-linear correlation. The Student-t tests indicate that the correlations are significant. The information of the figures are summarized in Table 29.

CONCLUSIONS

Stormwater modeling studies were conducted to determine runoff pollutant loadings for Austin area watersheds. The results of this study indicate that the water quality of the creeks depends on the both the quantity of stormwater runoff and the watershed development conditions. Specifically, the following conclusions can be drawn from the results of this study.

1. Regression equations were developed for Barton, Boggy, Bull and Shoal Creeks to correlate rainfall depth, runoff volume, and runoff pollutant load. For given rainfall depth of a storm, the runoff volume and in turn, the runoff pollutant load for each watershed for specific pollutant parameters (Fecal coliform, TSS, NO_3, NH_3, TP, TKN, TOC, or BOD) can be computed from the equations. The runoff pollutant loading rates (load per unit area per year) were computed for all the watersheds.

2. Each of the study watersheds represents a different level of multiple land use urban development which can be identified by the amount of impervious cover in the watershed. In general, the runoff amount and the runoff pollutant load increase with increasing amounts of impervious cover; an exception was TOC.

3. The baseline water quality for Barton, Bull, Boggy, Shoal, Bear, Walnut, and Williamson Creeks were studied. Concentrations of coliform bacteria, BOD, TDS, NO_3, and TP show significant increase with increasing impervious cover. The fecal coliform count for Shoal and Boggy Creeks are exceptionally high, with geometric means of 2,281 and 389 col/100 ml, respectively.

4. The stormwater average concentrations of TSS for Bull, Boggy and Shoal Creeks are high and increasing with watershed imperviousness. This may indicate that there is significant basin or river bank erosion in these watersheds.

5. The pollutant parameters such as toxics and heavy metals were not studied in this report because of insufficient data.

(10W01/4/study)

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APPENDIX

Tables and Figures

TABLE 1

STUDY AREAS AND SAMPLING STATIONS

Watershed/Creek	Sampling Station	Location	Drainage Area (sq. mi.)
Bull Creek	USGS 08154700	@ Loop 360	22.3
Barton Creek	USGS 08155200	@ Loop 360	116.0
Shoal Creek	USGS 08156750	@ 12th Street	12.8
Boggy Creek	USGS 08158050	@ Highway 183	13.1
Bear Creek	USGS 08158800	Below farm road near Driftwood	12.2
Walnut Creek	USGS 08158600	@ Webberville Road	51.3
Waller Creek	USGS 08157500	@ 23rd Street	4.13
Williamson Creek	USGS 08158970	@ Jimmy Clay Road	27.6
Northwest Austin/ Tributary Shoal Creek	NURP Site	@ Hart Lane	0.59
Rollingwood/ Tributary Town Lake	NURP Site	@ Rollingwood	0.094

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TABLE 2

WATERSHED DEVELOPMENT CONDITIONS

Land Use	Imperviousness[1] %	Bull Creek Area[2] %	Bull Creek Imp.[3] %	Barton Creek[4] Area %	Barton Creek Imp. %	Shoal Creek Area %	Shoal Creek Imp. %	Boggy Creek Area %	Boggy Creek Imp. %	Waller Creek Area %	Waller Creek Imp. %
Residential -											
Low Density	20	6	1.2	1	0.2	.3	0.6	0	0	0	0
Medium Density	40			1	0.4	30	12.0	26	10.4	31	12.4
High Density	60					5	3.0	15	9	5	3.0
Multi-Family	70					15	3.5			5	3.5
Commercial	50-80	0.5	0.3	0	0	7	4.6	7	3.5	6	3.9
Industrial	50-70	0.1	0.1	0	0	5	2.5	3	1.5	4	2.4
Street	100	2	2	0.4	0.4	16	16	13	13	15	15.0
Public	30	1	0.3	2	0.6	13	3.9	12	3.6	19	5.7
Undeveloped	8	88.4	7.1	95.6	7.7	16	1.3	24	1.9	15	1.0
Sum of (% Area x % Imp)			11.0		9.3		47.4		42.9		47.1
% Imp measured from Aerial Photo Map[5]			12.0		7.0		46.4		40.0		42.0

1 Impervious area estimates for various land use categories [based on the Hydroscience study (11)].

2 Percent of watershed in given land use [based on the City of Austin Planning Department data (10)].

3 Percent of watershed in given land use multiplied by percent imperviousness of that land use.

4 Watershed drainage areas and sampling/gauging station locations are listed in Table 1.

5 Percent imperviousness measured for other watersheds listed in Table 1 are: Bear Creek - 3%, Walnut Creek - 15%, and Williamson Creek - 15%.

TABLE 3

AVERAGE NUMBER OF RAINSTORMS[1]
AND AVERAGE RAINFALL DEPTH PER STORM[2]
FOR BULL CREEK WATERSHED
(1976 - 1982)

Month	Ave. No. Dry Days Between Storms	Average No. of Storms	Average Rainfall Depth Per Storm
Jan - Feb	6	6	0.48
Mar - Apr	8	6	0.92
May - June	10	7	1.26
Jul - Aug	10	5	0.63
Sep - Oct	7	6	0.91
Nov - Dec	8	5	0.77
Annual Values	8	35	0.84

1 Storms with rainfall depth greater than 0.05 inch

2 Depth measured in inches

10W01/4/tbl3

TABLE 4

AVERAGE NUMBER OF RAINSTORMS[1]
AND AVERAGE RAINFALL DEPTH PER STORM[2]
FOR BARTON CREEK WATERSHED
(1976 - 1982)

Month	Ave.No. Dry Days Between Storms	Average No. of Storms	Average Rainfall Depth Per Storm
Jan - Feb	6	6	0.53
Mar - Apr	7	7	1.18
May - June	7	7	0.94
Jul - Aug	13	5	0.94
Sep - Oct	7	6	0.97
Nov - Dec	7	6	0.75
Annual Values	8	37	0.90

1 Storms with rainfall depth greater than 0.05 inch

2 Depth measured in inches

10W01/4/tbl 4

TABLE 5

AVERAGE NUMBER OF RAINSTORMS[1]
AND AVERAGE RAINFALL DEPTH PER STORM[2]
FOR SHOAL CREEK WATERSHED
(1976 - 1982)

Month	Ave.No. Dry Days Between Storms	Average No. of Storms	Average Rainfall Depth Per Storm
Jan - Feb	7	6	0.52
Mar - Apr	7	7	1.09
May - June	7	7	2.00
Jul - Aug	8	5	0.72
Sep - Oct	7	7	0.99
Nov - Dec	7	6	0.67
Annual Values	7	38	0.84

1 Storms with rainfall depth greater than 0.05 inch

2 Depth measured in inches

10W01/4/tbl 5

TABLE 6

AVERAGE NUMBER OF RAINSTORMS[1]
AND AVERAGE RAINFALL DEPTH PER STORM[2]
FOR BOGGY CREEK WATERSHED
(1976 - 1982)

Month	Ave.No. Dry Days Between Storms	Average No. of Storms	Average Rainfall Depth Per Storm
Jan - Feb	7	6	0.54
Mar - Apr	7	7	0.90
May - June	7	7	1.43
Jul - Aug	9	4	1.05
Sep - Oct	7	6	0.98
Nov - Dec	7	6	0.65
Annual Values	7	36	0.93

1 Storms with rainfall depth greater than 0.05 inch
2 Depth measured in inches

10W01/4/tbl 6

TABLE 7

RUNOFF COEFFICIENTS FOR AUSTIN AREA WATERSHEDS[1]

Watersheds/Areas	Runoff Coefficients
Bull Creek above Loop 360 (Wet Condition)	0.12
Bull Creek above Loop 360 (Dry Condition)	0.03
Barton Creek Above Loop 360 (Wet Condition)	0.17
Shoal Creek Above Northwest Park	0.25
Shoal Creek Above White Rock Avenue	0.26
Shoal Creek Above 12th Street	0.27
Boggy Creek above Highway 183	0.23
Bear Creek above Driftwood	0.08
Waller Creek Above 23rd Avenue	0.34
Walnut Creek above Webberville Road	0.21
Williamson Creek above Jimmy Clay Rd.	0.17
NURP Northwest Austin Site[2]	0.17
NURP Rollingwood Site	0.05

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1 Runoff coefficients were developed for rainfall depth of less than 4 inches

2 NURP Northwest Austin Site is within the Recharge Zone.

10W01/4/tbl7

TABLE 8

STORMWATER RUNOFF POLLUTANT LOADING FOR BULL CREEK WATERSHED

Parameters*	Regression Equations**	No. Storms (No. Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q_W)***	$0.0558\ P^{1.8364}$	15	0.28 - 8.29	0.96
Runoff (Q_D)***	$0.0136\ P^{1.1621}$	11	0.34 - 3.27	0.59
Fecal Coliform (FC)	FC = 21 + 11274Q	5	0.04 - 0.37	0.99
	FC = 11210Q****	5	0.04 - 0.37	0.98
Total Suspended Solid (TSS)	TSS = 9.1 + 210Q	5	0.02 - 0.37	0.69
	TSS = 243Q	5	0.02 - 0.37	0.66
Nitrate (NO_3)	$NO_3 = 0.1013Q^{1.0124}$	6	0.02 - 0.37	0.95
Ammonia (NH_3)	$NH_3 = 0.0313Q^{1.2744}$	6	0.02 - 0.37	0.79
Total Kjeldahl Nitrogen (TKN)	TKN = 0.026 + 1.066Q	6	0.02 - 0.37	0.75
	TKN = 1.16Q	6	0.02 - 0.37	0.74
Total Phosphorous (TP)	TP = 0.0007 + 0.0636Q	6	0.02 - 0.37	0.82
	TP = 0.066Q	6	0.02 - 0.37	0.81
Total Organic Carbon (TOC)	TOC = 0.3 + 10.2Q	6	0.02 - 0.37	0.70
	TOC = 11.3Q	6	0.02 - 0.37	0.68
Biochem. Oxygen Demand (BOD_5)	$BOD_5 = 0.0059 + 2.1694Q$	5	0.02 - 0.37	0.94
	$BOD_5 = 2.191Q$	5	0.02 - 0.37	0.93

* Unit of parameters: Rainfall and runoff in inches; all other water quality parameters in pounds per acre.

** The student-t tests indicate that the relationships for all pollutant parameters are significant.

*** P represents rainfall depth (per storm) for Bull Creek watershed above the USGS monitoring station at Loop 360. Q represents stormwater runoff (per storm) of Bull Creek at the monitoring station. Q_W and Q_D represent Q under wet and dry antecedent watershed conditions. Wet condition indicates a weighted precipitation index of 0.5 inch or more for the past 30 days before the storm. Dry condition indicates an index less than 0.5 inch.

**** Linear equation through the origin

TABLE 9

STORMWATER RUNOFF POLLUTANT LOADING FOR BARTON CREEK WATERSHED

Parameters*	Regression Equations**	No. Storms (No. Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q_W)***	$Q_W = 0.097 + 0.217P$	17	0.62 - 7.03	0.82
	$Q_W = 0.187P$****	17	0.62 - 7.03	0.80
Runoff (Q_D) - no equation				
Total Suspended Solid (TSS)	$TSS = 244.3Q^{1.664}$	6	0.06 - 0.62	0.81
Nitrate (NO_3)	$NO_3 = 0.300Q^{0.6039}$	6	0.06 - 0.62	0.71
Ammonia (NH_3)	$NH_3 = 0.0536Q^{2.1966}$	5	0.06 - 0.62	0.87
Total Kjeldahl Nitrogen (TKN)	$TKN = 0.335Q^{0.9787}$	6	0.06 - 0.62	0.60
Total Phosphorous (TP)	$TP = 0.0648Q^{1.6812}$	5	0.06 - 0.62	0.81
Total Organic Carbon (TOC)	$TOC = 11.25Q^{1.615}$	6	0.06 - 0.62	0.67
Biochem. Oxygen Demand (BOD_5)	$BOD_5 = 1.178Q^{1.4752}$	6	0.06 - 0.62	0.79

* Unit of parameters: Rainfall and runoff in inches; all other water quality parameters in pounds per acre.

** The student-t tests indicate that the relationships for all pollutant parameters are significant

*** P represents rainfall depth (per storm) for Barton Creek watershed above the USGS monitoring station at Loop 360. Q represents stormwater runoff (per storm) of Barton Creek at the monitoring station. Q_W and Q_D represent Q under wet and dry antecedent watershed conditions. Wet condition indicates a weighted precipitation index of 0.5 inch or more for the past 30 days before the storm. Dry condition indicates an index less than 0.5 inch. Runoff equation for dry condition was not developed because of insufficient data.

**** Linear equation through the origin

10W01/4/tbl 9

TABLE 10

STORMWATER RUNOFF POLLUTANT LOADING
FOR SHOAL CREEK WATERSHED

Parameters*	Regression Equations***	No. of Storms (No. of Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q_1)**	$Q_1 = .0978P_1^{1.7952}$	17	1.0 - 8.4	0.90
Runoff (Q_2)**	$Q_2 = .1768P_2^{1.1591}$	14	1.0 - 4.0	0.82
Runoff (Q_3)**	$Q_3 = .1560P_3^{1.6248}$	19	1.0 - 8.3	0.84
Fecal Coliforms (FC)	$FC = -4,932 + 48,897Q_3$	3	0.19 - 0.5	0.80
	$FC = 32,264Q_3$****	3	0.19 - 0.5	0.75
Total Suspended Solid (TSS)	$TSS = 32 + 433Q_3$	6	0.19 - 1.1	0.81
	$TSS = 390Q_3$	6	0.19 - 1.1	0.80
Nitrate (NO_3)	$NO_3 = -0.020 + 0.171Q_3$	6	0.16 - 1.1	0.86
	$NO_3 = 0.143Q_3$	6	0.16 - 1.1	0.83
Ammonia (NH_3)	$NH_3 = -0.003 + 0.047Q_3$	6	0.16 - 1.1	0.98
	$NH_3 = 0.043Q_3$	6	0.16 - 1.1	0.97
Total Kjeldahl Nitrogen (TKN)	$TKN = 0.874Q^{1.4676}$	5	0.19 - 1.1	0.65
Total Phosphorous (TP)	$TP = -0.066 + 0.374Q_3$	6	0.16 - 1.1	0.82
	$TP = 0.280Q_3$	6	0.16 - 1.1	0.81
Biochem. Oxygen Demand (BOD_5)	$BOD_5 = 2.42Q_3^{1.1755}$	6	0.15 - 1.1	0.70

* Units of parameters: Rainfall and runoff in inches; fecal coliform in million (10^6) colonies per acre, and all other water quality parameters in pounds per acre.

** P_1, P_2, and P_3 represent rainfall depth (per storm) for the Shoal Creek watershed above the USGS monitoring stations at Northwest Park, White Rock, and 12th Street, respectively.
Q_1, Q_2, and Q_3 represent total stormwater runoff (per storm) of Shoal Creek at the three monitoring stations respectively.

*** The student-t tests indicate that the relationships for all pollutant parameters except TOC are significant.

**** Linear equation through the origin.

TABLE 11

STORMWATER RUNOFF POLLUTANT LOADING FOR BOGGY CREEK WATERSHED

Parameters*	Regression Equations***	No. Storms (No. Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q)**	$0.2346P^{1.0105}$	41	0.15 - 5.81	0.73
Total Suspended Solid (TSS)	$TSS = 212.2Q^{.8578}$	6	0.04 - 0.35	0.80
Nitrate (NO_3)	$NO_3 = 0.1407Q^{1.1695}$	8	0.04 - 0.35	0.84
Ammonia (NH_3)	$NH_3 = 0.0356Q^{1.203}$	8	0.04 - 0.35	0.62
Total Kjeldahl (TKN)	$TKN = 0.2132Q^{0.4292}$	8	0.04 - 0.35	0.67
Total Phosphorous (TP)	$TP = 0.0842Q^{0.4845}$	8	0.04 - 0.35	0.67
Total Organic Carbon (TOC)	$TOC = 0.63 + 2.48Q$	8	0.04 - 0.35	0.78
	$TOC = 4.83Q$****	8	0.34 - 0.35	0.77

* Unit of parameters: Rainfall and runoff in inches and all water quality parameters in pounds per acre.

** P represents rainfall depth (per storm) for Boggy Creek watershed above the USGS monitoring station at Highway 183. Q represents stormwater runoff (per storm) of Boggy Creek at the monitoring station.

*** The student-t tests indicate that the relationships for all pollutant parameters except BOD_5 and fecal coliforms are significant.

**** Linear equation through the origin.

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TABLE 12

STORMWATER RUNOFF POLLUTANT LOADING FOR TEST WATERSHED OF NURP PROJECT

Northwest Austin Site - Tributary of Shoal Creek

Parameters*	Regression Equations***	No. Storms (No. Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q)**	$Q = 0.0019 + 0.1676\,P$	22	0.04 - 4.32	0.77
	$Q = 0.17P$****	22	0.04 - 4.32	0.76
Nitrate (NO_3)	$NO_3 = 0.00024 + 0.332\,Q$	11	0.01 - 0.06	0.79
	$NO_3 = 0.341Q$	11	0.01 - 0.06	0.77
Ammonia (NH_3)	$NH_3 = 0.0010 + 0.338\,Q$	11	0.01 - 0.06	0.70
	$NH_3 = 0.370Q$	11	0.01 - 0.06	0.68
Total Kjedahl Nitrogen (TKN)	$TKN = 1.578\,Q^{1.2740}$	15	0.003 - 0.07	0.74
Total Phosphorus (TP)	$TP = 0.0006 + 0.092\,Q$	14	0.02 - 0.07	0.52
	$TP = 0.097Q$	14	0.02 - 0.07	0.50
Total Organic Carbon (TOC)	$TOC = 3.887\,Q^{1.0609}$	13	0.01 - 0.07	0.73
Chemical Oxygen Demand (COD)	$COD = 63.48\,Q^{1.4080}$	11	0.003 - 0.06	0.85
Total Dissolved Solid (TDS)	$TDS = 59.2\,Q^{1.0741}$	11	0.003 - 0.06	0.92

* Unit of parameters: Rainfall and runoff in inches; all other water quality parameters in pounds per acre.

** P represents rainfall depth (per storm) for the test watershed.
Q represents stormwater runoff (per storm) from the test watershed.

*** The student-t tests indicate that the relationships for the pollutant parameters shown are significant.

**** Linear equation through the origin.

TABLE 13

STORMWATER RUNOFF POLLUTANT LOADING FOR TEST WATERSHED OF NURP PROJECT

Rollingwood Site

Parameters*	Regression Equations***	No. Storms (No. Data Points)	Valid Range (Values of Ind. Var.)	Coefficient of Determination (R^2)
Runoff (Q)**	$Q = -0.0182 + 0.054\ P$	26	0.12 - 4.25	0.82
	$Q = 0.045P$****	26	0.12 - 4.25	0.80
Nitrate (NO_3)	$NO_3 = 0.00062 + 0.169\ Q$	10	0.002 - 0.063	0.83
	$NO_3 = 0.175Q$	10	0.002 - 0.063	0.82
Ammonia (NH_3)	$NH_3 = 0.906\ Q^{0.696}$	10	0.002 - 0.063	0.75
Chemical Oxygen Demand (COD)	$COD = 0.085 + 12.63\ Q$	10	0.002 - 0.063	0.67
	$COD = 13.1Q$	10	0.002 - 0.063	0.65
Total Dissolved Solid (TDS)	$TDS = 77.11\ Q^{0.8217}$	10	0.002 - 0.063	0.66

* Unit of parameters: Rainfall and runoff in inches; all other water quality parameters in pounds per acre.

** P represents rainfall depth (per storm) for the test watershed.
Q represents stormwater runoff (per storm) from the test watershed.

*** The student-t tests indicate that the relatinships for the pollutant parameters shown are significant.

**** Linear equation through the origin.

10W01/4/tbl 13

TABLE 14
ESTIMATED AVERAGE MONTHLY AND ANNUAL LOADING FOR
BULL CREEK WATERSHED ABOVE USGS MONITORING STATION
AT LOOP 360

	WATER QUALITY PARAMETERS								
MONTH	FC	BOD	TDS	TSS	NO3	NH3	TKN	TOC	TP
JAN	623	.12	3.0	13.0	.005	.001	.06	.6	.004
FEB	1337	.26	6.4	27.8	.012	.002	.14	1.3	.008
MAR	2841	.56	13.6	59.2	.025	.006	.30	2.9	.017
APR	4303	.84	20.6	89.6	.038	.009	.45	4.3	.025
MAY	9249	1.81	44.3	192.6	.083	.021	.96	9.3	.054
JUN	7703	1.51	36.9	160.4	.069	.019	.80	7.8	.045
JUL	1483	.29	7.1	30.9	.013	.002	.15	1.5	.009
AUG	756	.15	3.6	15.7	.007	.001	.08	.8	.004
SEP	2667	.52	12.8	55.5	.024	.004	.28	2.7	.016
OCT	3651	.71	17.5	76.0	.033	.008	.38	3.7	.021
NOV	2086	.41	10.0	43.4	.018	.004	.22	2.1	.012
DEC	1361	.27	6.5	28.3	.012	.002	.14	1.4	.008
TOTAL	38059	7.44	182.3	792.4	.339	.079	3.95	38.4	.224

THE UNIT OF FECAL COLIFORM IS MILLION COLONIES PER ACRE.

ALL OTHER UNITS ARE POUNDS PER ACRE.

TABLE 15
ESTIMATED AVERAGE MONTHLY AND ANNUAL STORM LOADING FOR BARTON CREEK WATERSHED ABOVE USGS MONITORING STATION AT LOOP 360

	WATER QUALITY PARAMETERS						
MONTH	BOD	TSS	NO3	NH3	TKN	TOC	TP
JAN	.08	12.1	.012	.001	.05	.6	.012
FEB	.11	17.8	.014	.002	.07	.9	.014
MAR	.24	40.9	.022	.006	.13	2.0	.024
APR	.77	146.9	.034	.027	.28	6.9	.040
MAY	.53	95.0	.036	.015	.24	4.5	.040
JUN	.73	143.6	.027	.028	.24	6.7	.035
JUL	.23	39.5	.017	.005	.11	1.9	.019
AUG	.14	23.8	.011	.003	.07	1.1	.012
SEP	.40	71.0	.029	.011	.19	3.4	.031
OCT	.39	72.4	.023	.012	.17	3.4	.027
NOV	.20	34.3	.018	.005	.11	1.7	.019
DEC	.10	16.2	.012	.002	.06	.8	.012
TOTAL	3.91	713.6	.256	.116	1.72	33.9	.285

UNITS ARE POUNDS PER ACRE.

TABLE 16
ESTIMATED AVERAGE MONTHLY AND ANNUAL STORM LOADING FOR SHOAL CREEK WATERSHED ABOVE USGS MONITORING STATION AT 12TH STREET

	WATER QUALITY PARAMETERS						
MONTH	FC	BOD	TSS	NO3	NH3	TKN	TP
JAN	4524	.37	54.6	.020	.006	.04	.039
FEB	10796	.89	130.4	.048	.014	.18	.094
MAR	18507	1.52	223.6	.082	.025	.37	.161
APR	36511	3.00	441.1	.162	.049	.47	.317
MAY	71390	5.87	862.4	.316	.095	.67	.620
JUN	51809	4.26	625.9	.230	.069	.22	.450
JUL	16456	1.35	198.8	.073	.022	.32	.143
AUG	4707	.39	56.9	.021	.006	.06	.041
SEP	21833	1.80	263.7	.097	.029	.37	.189
OCT	20828	1.71	251.6	.092	.028	.33	.181
NOV	13180	1.08	159.2	.058	.018	.24	.114
DEC	9666	.79	116.8	.043	.013	.17	.084
TOTAL	280207	23.04	3384.9	1.242	.373	3.42	2.432

THE UNIT OF FECAL COLIFORM IS MILLION COLONIES PER ACRE.

ALL OTHER UNITS ARE POUNDS PER ACRE.

TABLE 17
ESTIMATED AVERAGE MONTHLY AND ANNUAL STORM
LOADING FOR BOGGY CREEK WATERSHED ABOVE
USGS MONITORING STATION AT HWY 183

	WATER QUALITY PARAMETERS					
MONTH	TSS	NO3	NH3	TKN	TOC	TP
JAN	36.8	.014	.003	.10	2.1	.026
FEB	100.1	.049	.012	.17	3.1	.031
MAR	127.7	.064	.016	.21	3.8	.046
APR	242.6	.131	.033	.33	6.0	.065
MAY	386.4	.211	.052	.51	9.3	.112
JUN	258.0	.152	.038	.29	6.2	.084
JUL	219.0	.124	.031	.27	5.2	.058
AUG	31.3	.013	.003	.07	1.4	.017
SEP	206.5	.106	.026	.31	5.2	.054
OCT	154.6	.079	.019	.24	4.5	.067
NOV	95.9	.047	.012	.17	3.1	.046
DEC	100.1	.049	.012	.16	2.9	.030
TOTAL	1959.0	1.039	.257	2.82	52.7	.635

UNITS ARE POUNDS PER ACRE.

TABLE 18
STORMWATER POLLUTANT LOADING OF
AUSTIN CREEKS FOR VARIOUS SIZE
OF RAINSTORM EVENTS

	FECAL COLIFORM (MIL. COL. PER ACRE)					TSS (POUNDS PER ACRE)					NO3 (POUNDS PER ACRE)				
RAINFALL	PERCENT IMPERVIOUS COVER					PERCENT IMPERVIOUS COVER					PERCENT IMPERVIOUS COVER				
(INCHES)	10	20	30	40	45	10	20	30	40	45	10	20	30	40	45
.5	90	510	940	1360	1570	16	20	25	29	31	.00	.01	.01	.01	.01
1.0	370	1650	2900	4200	4900	33	44	55	66	71	.01	.01	.02	.03	.03
2.0	1460	5300	9200	13100	15000	72	101	130	159	173	.02	.04	.05	.07	.08
3.0	3200	10600	17900	25300	29000	117	169	222	274	300	.04	.07	.10	.13	.14
4.0	5700	17300	28900	40500	46200	169	249	330	410	450	.05	.10	.15	.20	.22

	NH3 (POUNDS PER ACRE)					TKN (POUNDS PER ACRE)					TP (POUNDS PER ACRE)				
RAINFALL	PERCENT IMPERVIOUS COVER					PERCENT IMPERVIOUS COVER					PERCENT IMPERVIOUS COVER				
(INCHES)	10	20	30	40	45	10	20	30	40	45	10	20	30	40	45
.5	.001	.001	.002	.003	.003	.04	.05	.05	.05	.05	.004	.010	.016	.022	.025
1.0	.001	.003	.005	.007	.008	.07	.08	.08	.09	.09	.008	.019	.030	.042	.048
2.0	.006	.010	.015	.020	.022	.13	.16	.20	.23	.25	.018	.038	.060	.084	.096
3.0	.013	.021	.028	.035	.039	.18	.28	.39	.49	.54	.030	.063	.098	.134	.153
4.0	.025	.035	.044	.054	.059	.22	.44	.66	.88	.99	.043	.090	.138	.188	.213

THIS TABLE IS A SUMMARY OF FIGURES 10-15. THE STORM EVENT LOADING EQUATIONS PRESENTED IN TABLES 8-11 AND THE IMPERVIOUS COVER VALUES IN TABLE 2 WERE USED AS THE BASIS FOR THE LINEAR CORRELATIONS PRESENTED IN FIGURES 10-15.

TABLE 19
STORMWATER RUNOFF POLLUTANT AVERAGE CONCENTRATIONS
FOR AUSTIN AREA WATERSHEDS

PARAMETER	BARTON CREEK	BULL CREEK	BOGGY CREEK	SHOAL CREEK
BOD	3.30	9.70	11.60	10.40
FCOL	7800.00	10900.00	NA	31400.00
TSS	607.00	1030.00	1030.00	1720.00
NO3	.19	.44	.62	.63
NH3	.12	.10	.16	.19
TKN	1.50	NA	.70	3.50
TOC	33.00	50.00	21.00	17.00
TP	.12	.29	.29	1.24

THE UNIT OF FECAL COLIFORM IS COLONIES PER 100ML (COL/100ML).

THE UNIT OF ALL OTHER PARAMETERS IS MILLIGRAMS PER LITER (MG/L).

TABLE 20 BASELINE CONDITIONS FOR AUSTIN CREEKS

SITE	FLOW (CFS)	BOD (MG/L)	FCOL (COL/ 100ML)	TSS (MG/L)	TDS (MG/L)	NO3 (MG/L)	NH3 (MG/L)	TON (MG/L)	TKN (MG/L)	TP (MG/L)	TOC (MG/L)
BARTON CREEK AT LOOP 360 AND HIGHWAY 71	1.9	.4	19	1	244	.11	.02	.16	.17	.01	3.3
BARTON CREEK BELOW BARTON SPRINGS	84.0	.2	26	2	321	1.00	.01	.14	.16	.01	2.0
BULL CREEK AT LOOP 360 AND FM 2222	2.1	.5	30	4	353	.11	.03	.20	.25	.01	4.1
BOGGY CREEK AT HIGHWAY 183	.5	.5	389	4	405	.47	.02	.21	.24	.03	3.9
SHOAL CREEK AT 12TH STREET	.7	.6	2281	2	428	.47	.03	.33	.36	.03	3.4
WALNUT CREEK AT WEBBERVILLE ROAD	4.4	.6	189	4	344	.47	.02	.30	.32	.02	4.0
BEAR CREEK BELOW FM 1826 NEAR DRIFTWOOD	1.8	.3	59	1	292	.17	.05	.15	.18	.01	2.7
WILLIAMSON CREEK AT JIMMY CLAY ROAD	2.4	1.5	165	5	410	.62	.48	.42	.86	.03	4.8

TABLE 21
BULL CREEK WATER QUALITY
(AT LOOP 360 AND FM 2222)
BASELINE CONDITIONS 1975-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	2.10	.18/18	4.70	1.10	.70	3.50
BOD(MG/L)	LOG-NORMAL	.50	.1/1.4	.62	.90	.38	.45
FCOL(COL/100ML)	LOG-NORMAL	30.00	1/640	19.00	87.00	93.00	13.00
TSS(MG/L)	LOG-NORMAL	4.00	0/25	7.00	16.00	3.00	3.00
TDS(MG/L)	NORMAL	353.00	243/420	243.00	293.00	377.00	373.00
NO3(MG/L)	NORMAL	.11	0/.55	.13	.03	.05	.17
NH3(MG/L)	NORMAL	.03	0/.10	.04	.03	.03	.02
TON(MG/L)	LOG-NORMAL	.20	0/.52	.24	.36	.32	.12
TKN(MG/L)	LOG-NORMAL	.25	.05/.53	.30	.38	.34	.16
TP(MG/L)	LOG-NORMAL	.01	0/.06	.01	.02	.01	.01
TOC(MG/L)	LOG-NORMAL	4.10	2.0/11	4.40	4.40	4.50	3.70

TABLE 24
SHOAL CREEK WATER QUALITY
(AT 12TH STREET)
BASELINE CONDITIONS 1975-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	.60	0/4.3	.70	NA	NA	.26
BOD(MG/L)	LOG-NORMAL	.62	0/1.5	1.02	NA	NA	.67
FCOL(COL/100ML)	LOG-NORMAL	2281.00	310/24000	4440.00	1715.00	NA	2670.00
TSS(MG/L)	LOG-NORMAL	2.00	0/27	14.00	NA	NA	NA
TDS(MG/L)	NORMAL	428.00	349/515	NA	NA	NA	473.00
NO3(MG/L)	NORMAL	.47	.10/.84	.34	.13	NA	.66
NH3(MG/L)	NORMAL	.03	0/.10	.05	.07	NA	.03
TON(MG/L)	LOG-NORMAL	.33	.21/.52	.42	NA	NA	.30
TKN(MG/L)	LOG-NORMAL	.36	.22/.62	.47	NA	NA	.32
TP(MG/L)	LOG-NORMAL	.03	.01/.09	.03	NA	NA	.04
TOC(MG/L)	LOG-NORMAL	3.40	2.0/5.6	3.00	NA	NA	3.04

TABLE 25
BOGGY CREEK WATER QUALITY
(AT HIGHWAY 183)
BASELINE CONDITIONS 1975-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	.50	.03/6.3	.60	.80	1.00	.30
BOD(MG/L)	LOG-NORMAL	.51	.2/4.9	.68	.50	.42	.46
FCOL(COL/100ML)	LOG-NORMAL	389.00	25/8000	556.00	1238.00	606.00	144.00
TSS(MG/L)	LOG-NORMAL	4.00	0/98	9.00	9.00	3.00	2.00
TDS(MG/L)	NORMAL	405.00	306/504	418.00	353.00	438.00	420.00
NO3(MG/L)	NORMAL	.47	0/1.2	.33	.47	.39	.58
NH3(MG/L)	NORMAL	.02	0/.12	.03	.03	.01	.01
TON(MG/L)	LOG-NORMAL	.21	0/.91	.27	.28	.47	.13
TKN(MG/L)	LOG-NORMAL	.24	0/.92	.30	.31	.48	.14
TP(MG/L)	LOG-NORMAL	.03	0/.12	.04	.04	.03	.03
TOC(MG/L)	LOG-NORMAL	3.90	1.2/15	5.30	4.80	3.80	2.90

TABLE 26
BEAR CREEK WATER QUALITY
(BELOW FARM ROAD 1826 NEAR DRIFTWOOD)
BASELINE CONDITIONS 1975-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	1.80	.06/30	NA	NA	NA	1.90
BOD(MG/L)	LOG-NORMAL	.27	0/.8	NA	NA	NA	.36
FCOL(COL/100ML)	LOG-NORMAL	59.00	6/420	NA	NA	NA	27.00
TSS(MG/L)	LOG-NORMAL	1.00	0/3	NA	NA	NA	1.00
TDS(MG/L)	NORMAL	292.00	270/310	NA	NA	NA	288.00
NO3(MG/L)	NORMAL	.17	0/.45	NA	NA	NA	.20
NH3(MG/L)	NORMAL	.05	0/.18	NA	NA	NA	.03
TON(MG/L)	LOG-NORMAL	.15	0/.64	NA	NA	NA	.23
TKN(MG/L)	LOG-NORMAL	.18	0/.70	NA	NA	NA	.25
TP(MG/L)	LOG-NORMAL	.01	0/.04	NA	NA	NA	.02
TOC(MG/L)	LOG-NORMAL	2.70	1.3/7.9	NA	NA	NA	4.40

TABLE 27
WILLIAMSON CREEK WATER QUALITY
(AT JIMMY CLAY ROAD)
BASELINE CONDITIONS 1976-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	2.40	.26/24	5.30	.90	2.00	2.70
BOD(MG/L)	LOG-NORMAL	1.50	.3/5.8	1.43	1.19	1.33	1.78
FCOL(COL/100ML)	LOG-NORMAL	165.00	14/720	184.00	187.00	247.00	112.00
TSS(MG/L)	LOG-NORMAL	4.80	0/29	4.00	8.00	7.00	3.00
TDS(MG/L)	NORMAL	410.00	335/534	397.00	410.00	446.00	397.00
NO3(MG/L)	NORMAL	.62	.26/1.2	.54	.70	.64	.61
NH3(MG/L)	NORMAL	.48	0/1.3	.26	.34	.71	.61
TON(MG/L)	LOG-NORMAL	.42	.18/1.2	.44	.41	.41	.43
TKN(MG/L)	LOG-NORMAL	.86	0/1.1	.73	.70	1.05	.99
TP(MG/L)	LOG-NORMAL	.03	0/1.1	.04	.02	.02	.05
TOC(MG/L)	LOG-NORMAL	4.80	2.4/9.9	4.70	4.40	4.40	5.20

TABLE 28
WALNUT CREEK WATER QUALITY
(AT WEBBERVILLE ROAD)
BASELINE CONDITIONS 1976-1982

WATER QUALITY PARAMETER	SAMPLING DISTRIBUTION	MEAN OR GEOMETRIC MEAN	RANGE (MIN/MAX)	SPRING	SUMMER	FALL	WINTER
FLOW(CFS)	LOG-NORMAL	4.40	.07/25	8.40	1.10	2.40	7.10
BOD(MG/L)	LOG-NORMAL	.59	.2/4.1	.59	.30	.36	1.05
FCOL(COL/100ML)	LOG-NORMAL	139.00	29/1100	307.00	480.00	182.00	98.00
TSS(MG/L)	LOG-NORMAL	344.00	235/392	363.00	296.00	337.00	352.00
TDS(MG/L)	NORMAL	4.00	0/46	9.00	3.00	2.00	3.00
NO3(MG/L)	NORMAL	.47	.01/1.2	.81	.49	.23	.41
NH3(MG/L)	NORMAL	.02	0/.07	.02	.03	.01	.03
TON(MG/L)	LOG-NORMAL	.30	.16/.83	.26	.41	.30	.30
TKN(MG/L)	LOG-NORMAL	.32	.19/.90	.27	.43	.31	.32
TP(MG/L)	LOG-NORMAL	.02	0/.11	.01	.02	.02	.01
TOC(MG/L)	LOG-NORMAL	4.00	2.0/9.5	5.20	4.70	3.40	3.50

TABLE 29
BASELINE WATER QUALITY CONDITIONS
FOR AUSTIN CREEKS

WATERSHED IMPERV. COVER (PERCENT)	BOD (MG/L)	AVERAGE CONCENTRATION FCOL (COL/ 100ML)	TDS (MG/L)	NO3 (MG/L)	TP (MG/L)
10	.5	38	298	.16	.01
20	.5	181	354	.28	.02
30	.6	451	391	.38	.02
40	.6	862	420	.48	.03
45	.6	1135	433	.53	.03

THIS TABLE IS A SUMMARY OF FIGURES 16-21. THE AVERAGE BASELINE CONCENTRATION VALUES FOR ALL THE CREEKS ARE PRESENTED IN TABLES 20-28 AND THE IMPERVIOUS COVER VALUES IN TABLE 2 WERE USED AS THE BASIS FOR THESE LINEAR AND NONLINEAR CORRELATIONS PRESENTED IN FIGURES 16-21.

THERE IS NOT SUFFICIENT DATA TO DEVELOP A RELATIONSHIP FOR TSS.

THE STUDENT'S T-TEST INDICATES THAT THERE IS NO SIGNIFICANT RELATIONSHIP FOR THE FOLLOWING PARAMETERS: NH3:TON:TKN:TOC.

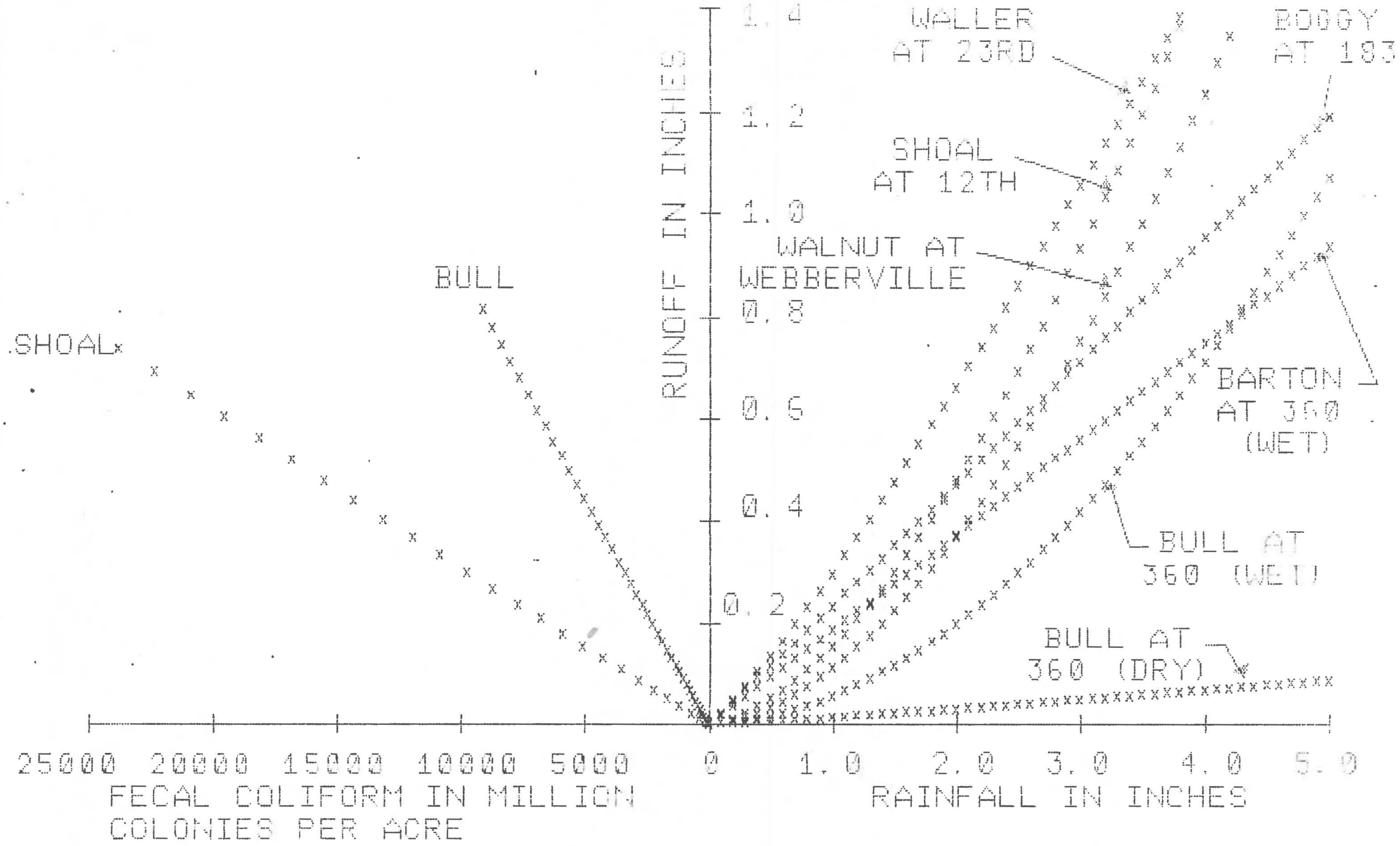


FIGURE 1. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP-FECAL COLIFORM

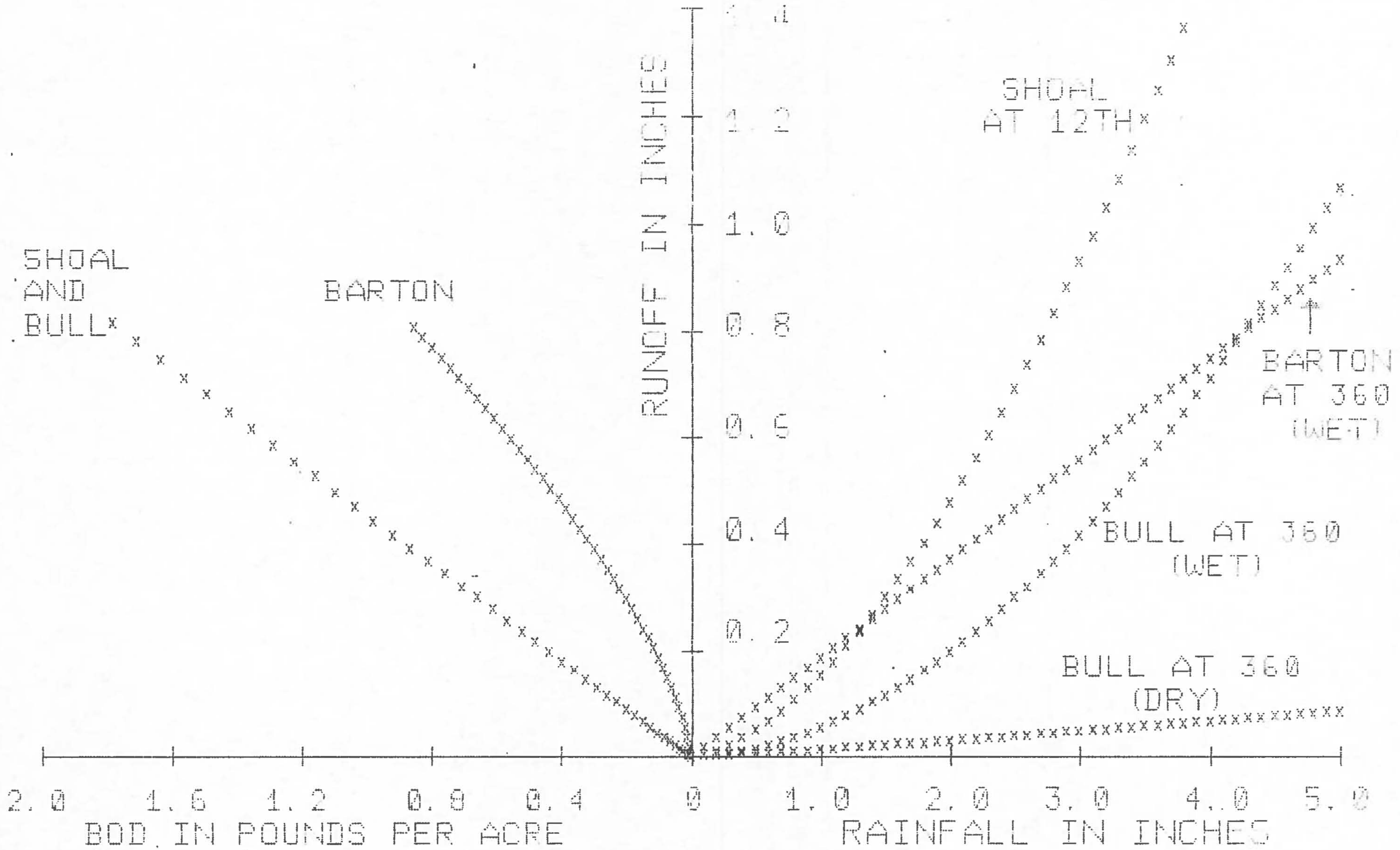


FIGURE 2. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR BOD

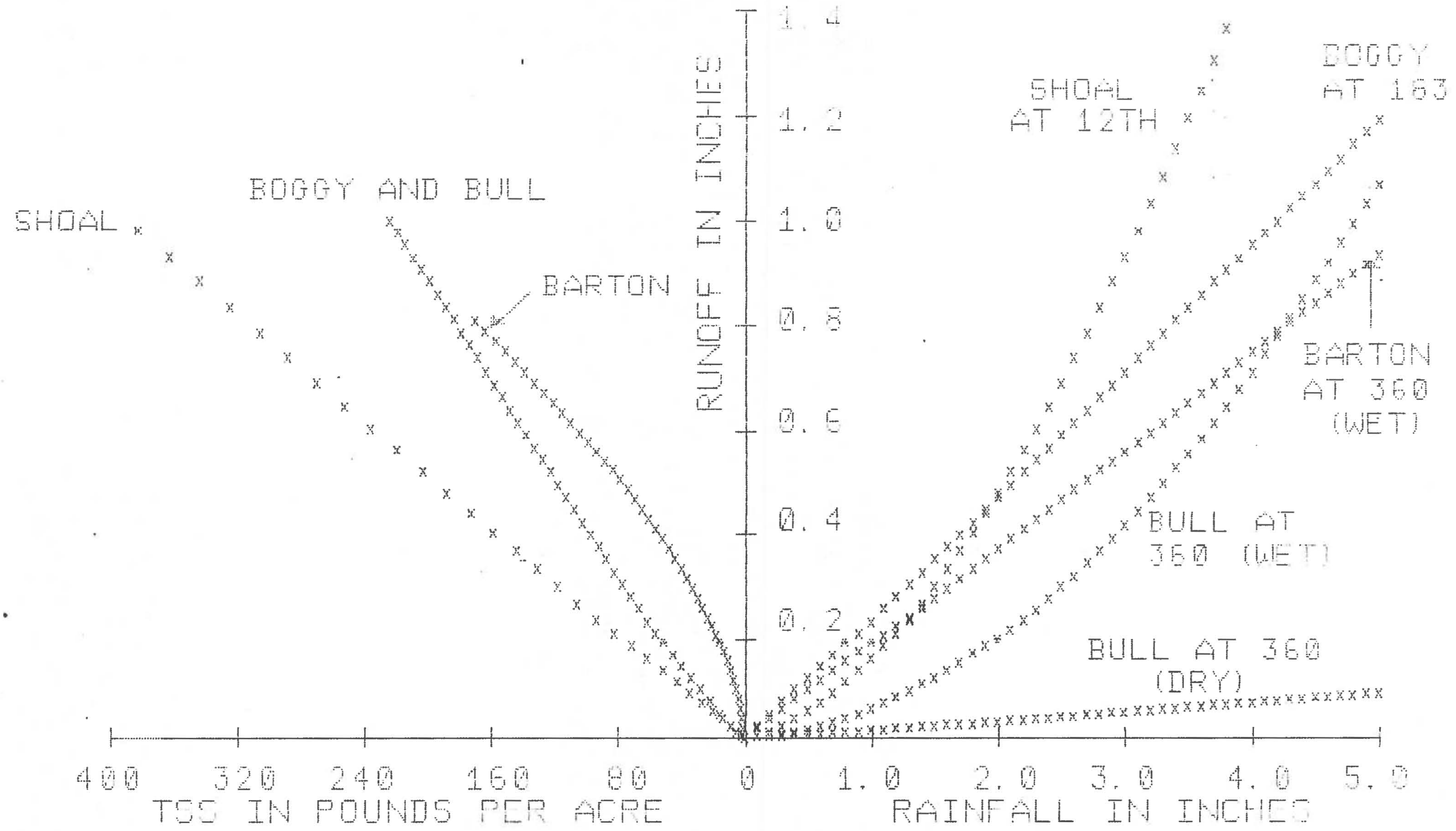


FIGURE 3. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR TSS

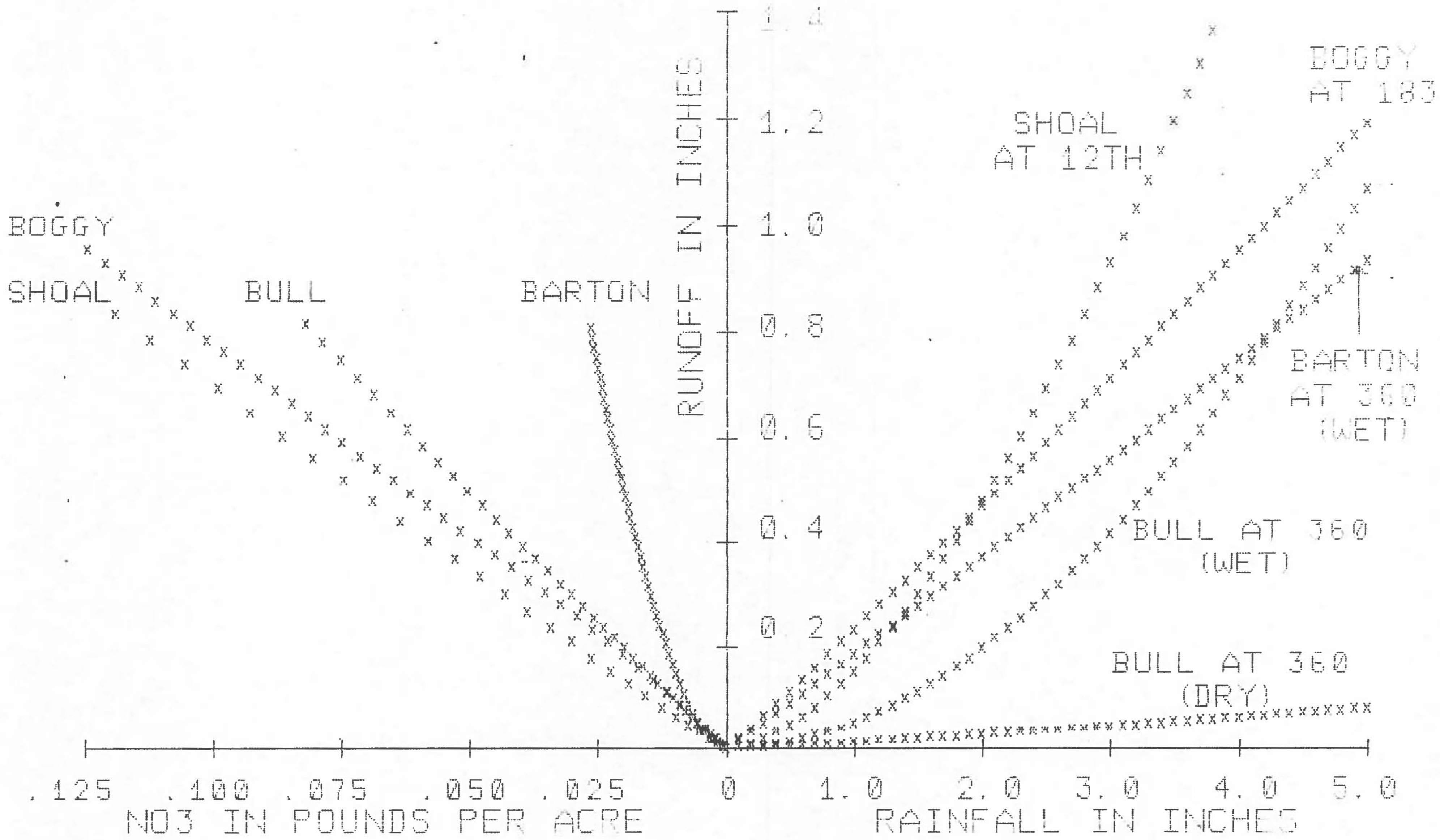


FIGURE 4. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR NO3

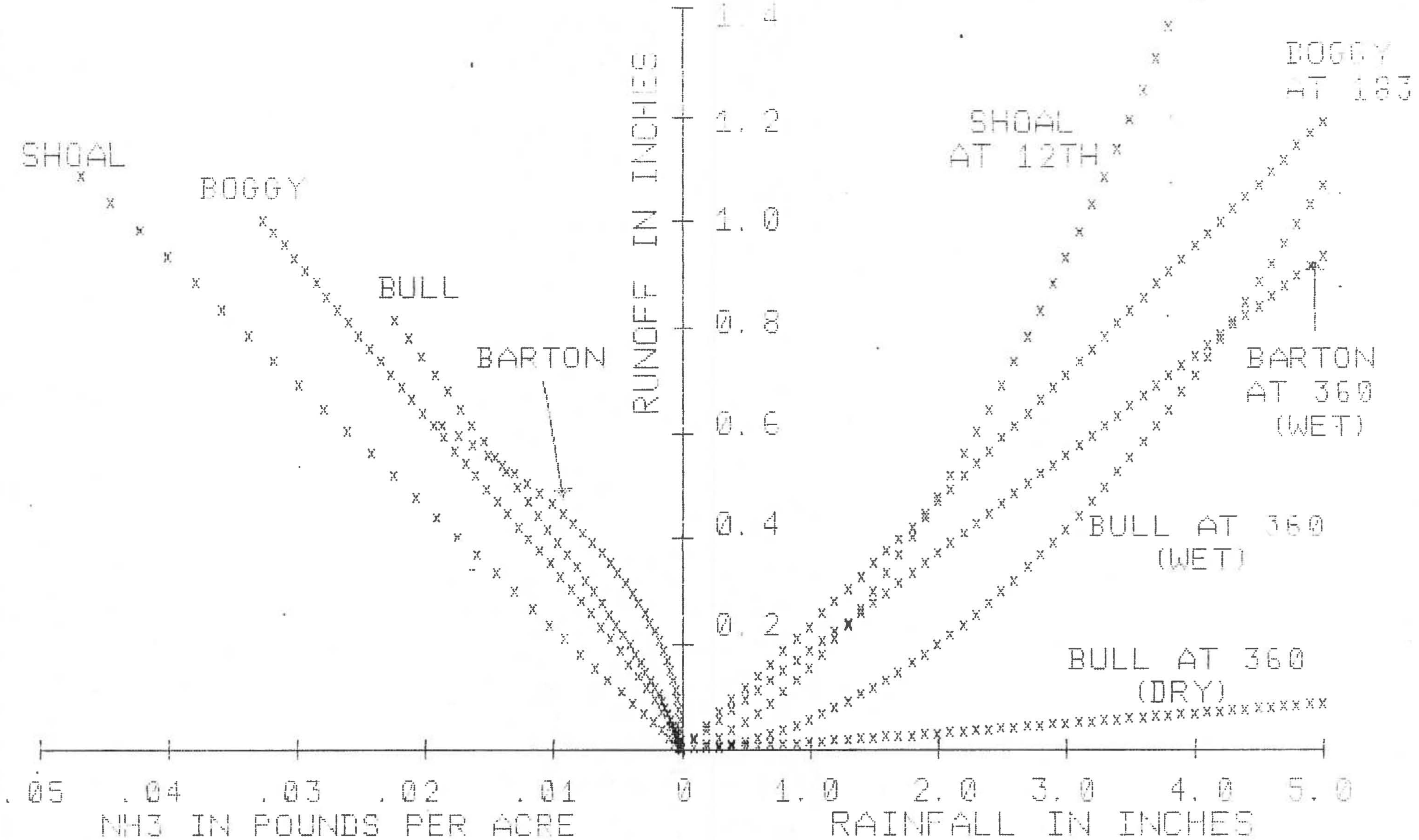


FIGURE 5. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR NH3

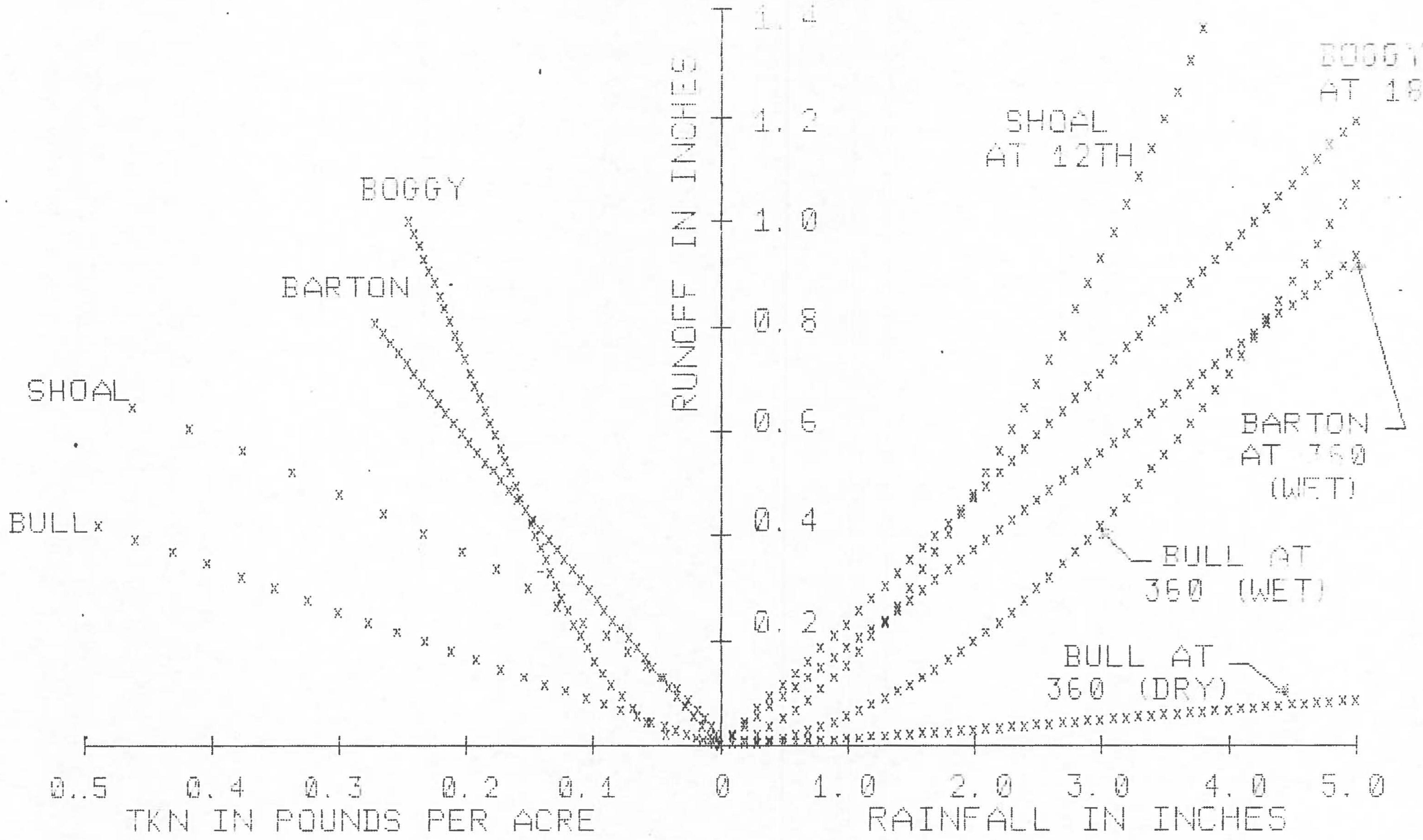


FIGURE 6. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR TKN

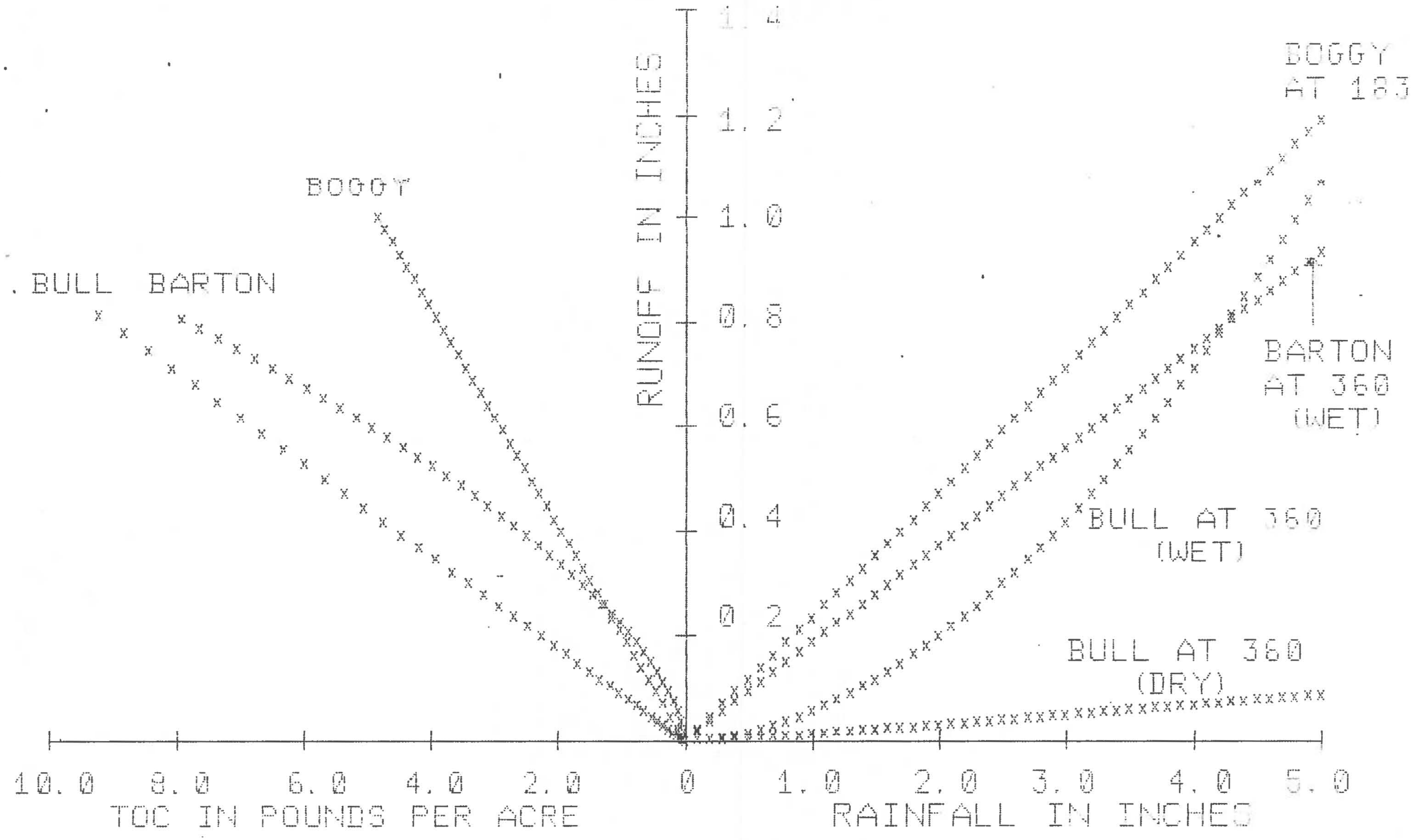


FIGURE 7. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR TOC

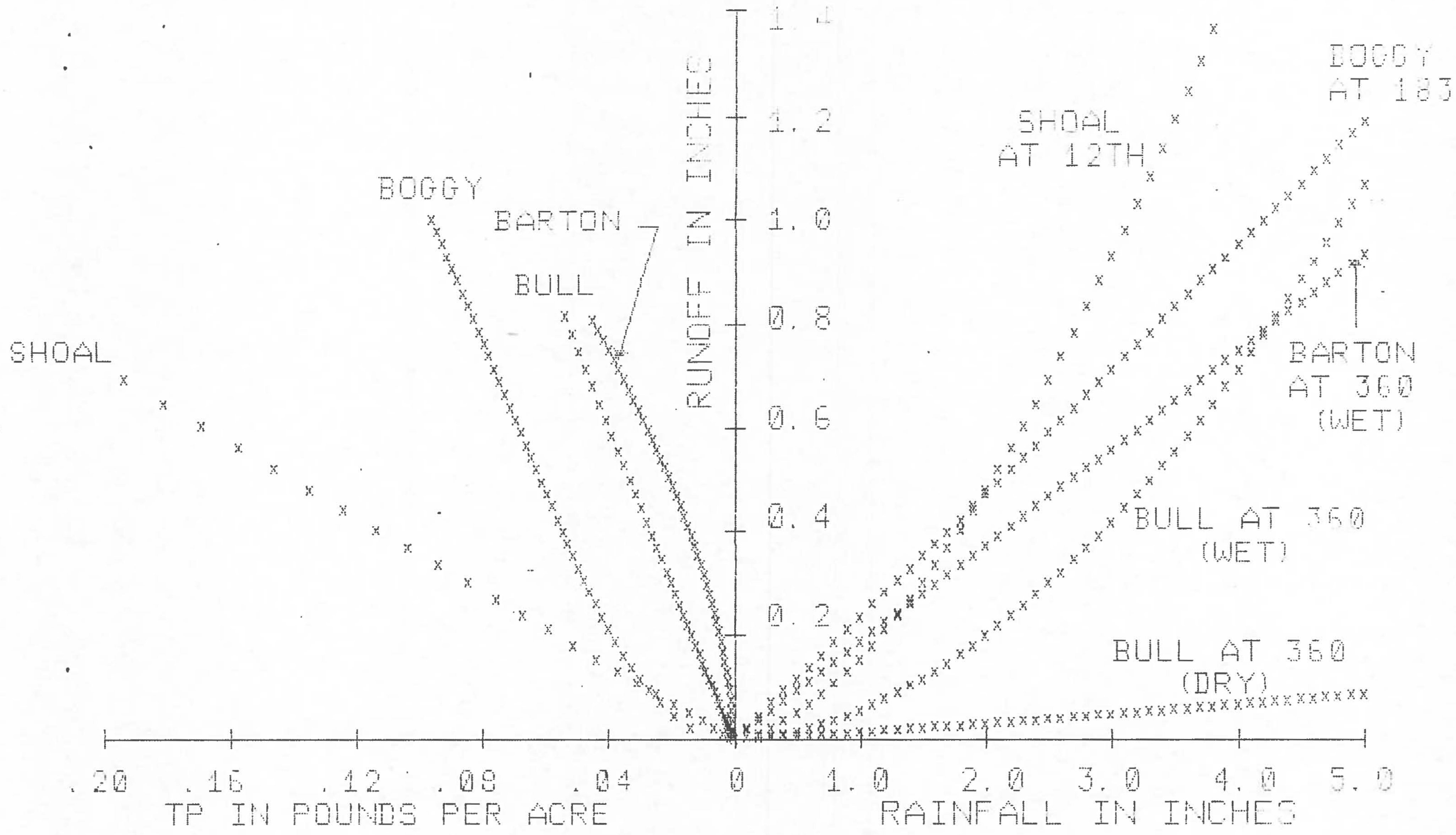


FIGURE 8. STORM LOAD-RUNOFF-RAINFALL RELATIONSHIP FOR TP

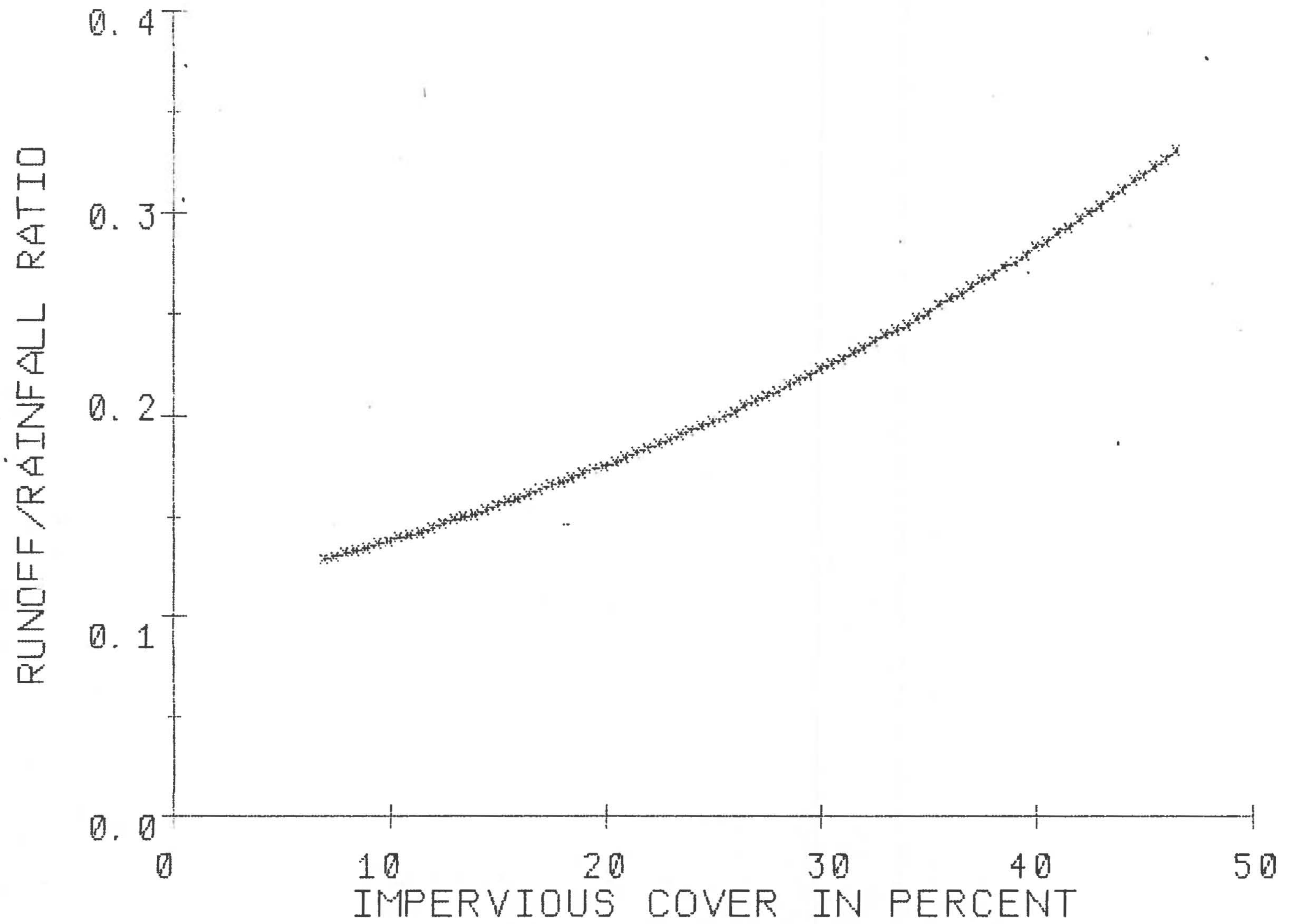


FIGURE 9. AVERAGE RUNOFF/RAINFALL RATIO PER STORM IN TERMS OF WATERSHED IMPERVIOUSNESS FOR AUSTIN CREEKS (RAINFALL LESS THAN 4 INCHES ONLY)

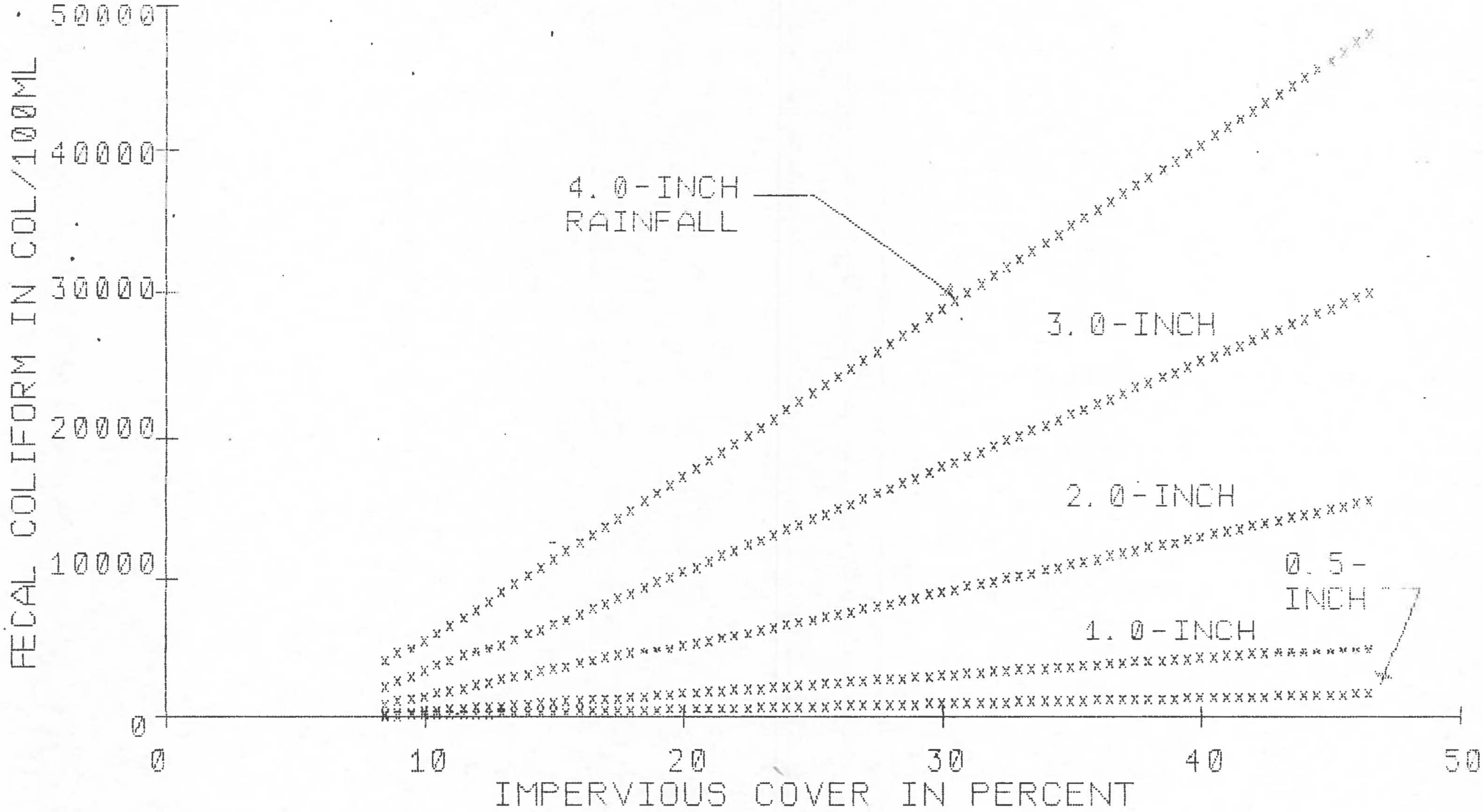


FIGURE 10. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - FECAL COLIFORM

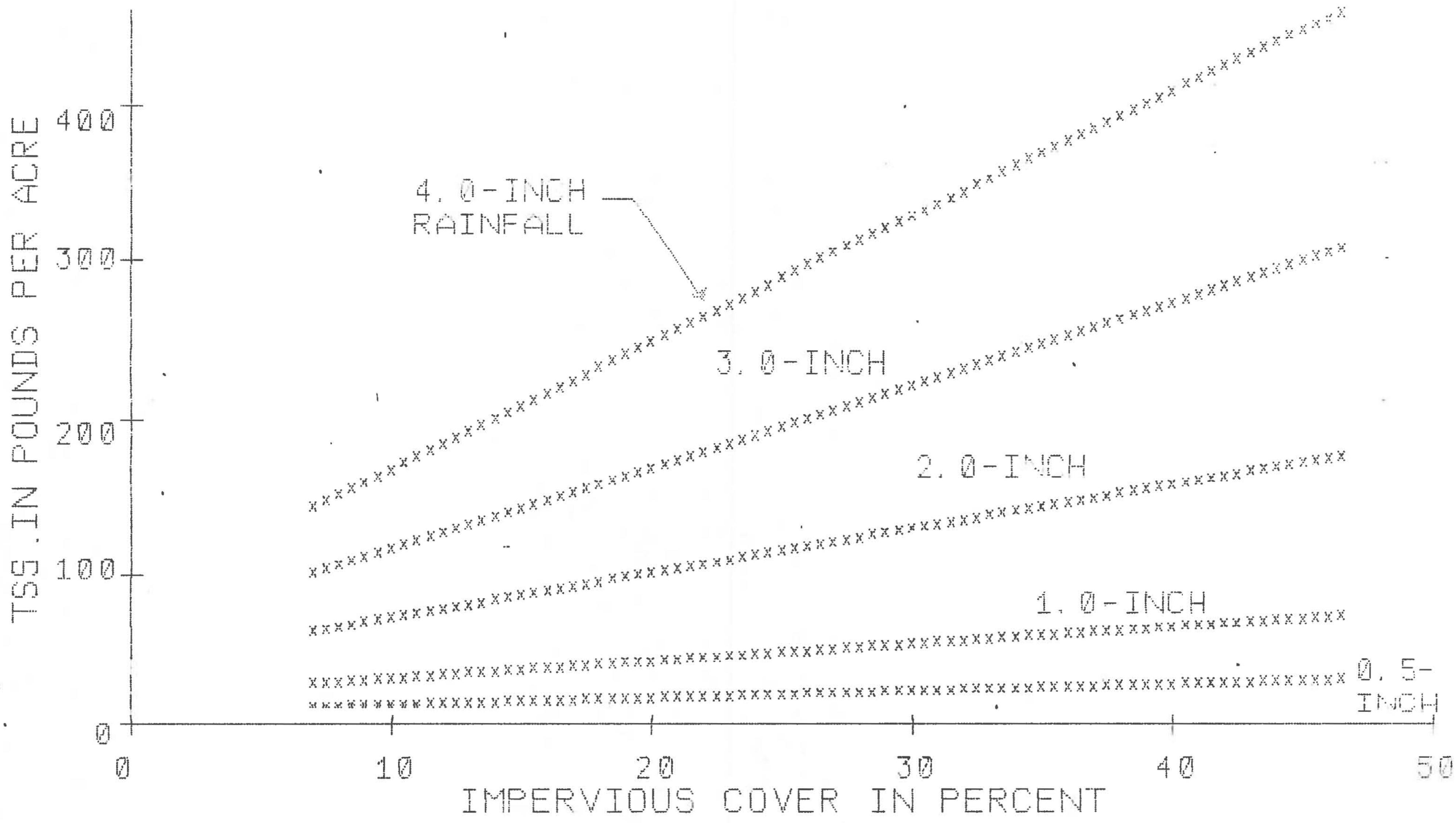


FIGURE 11. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - TSS

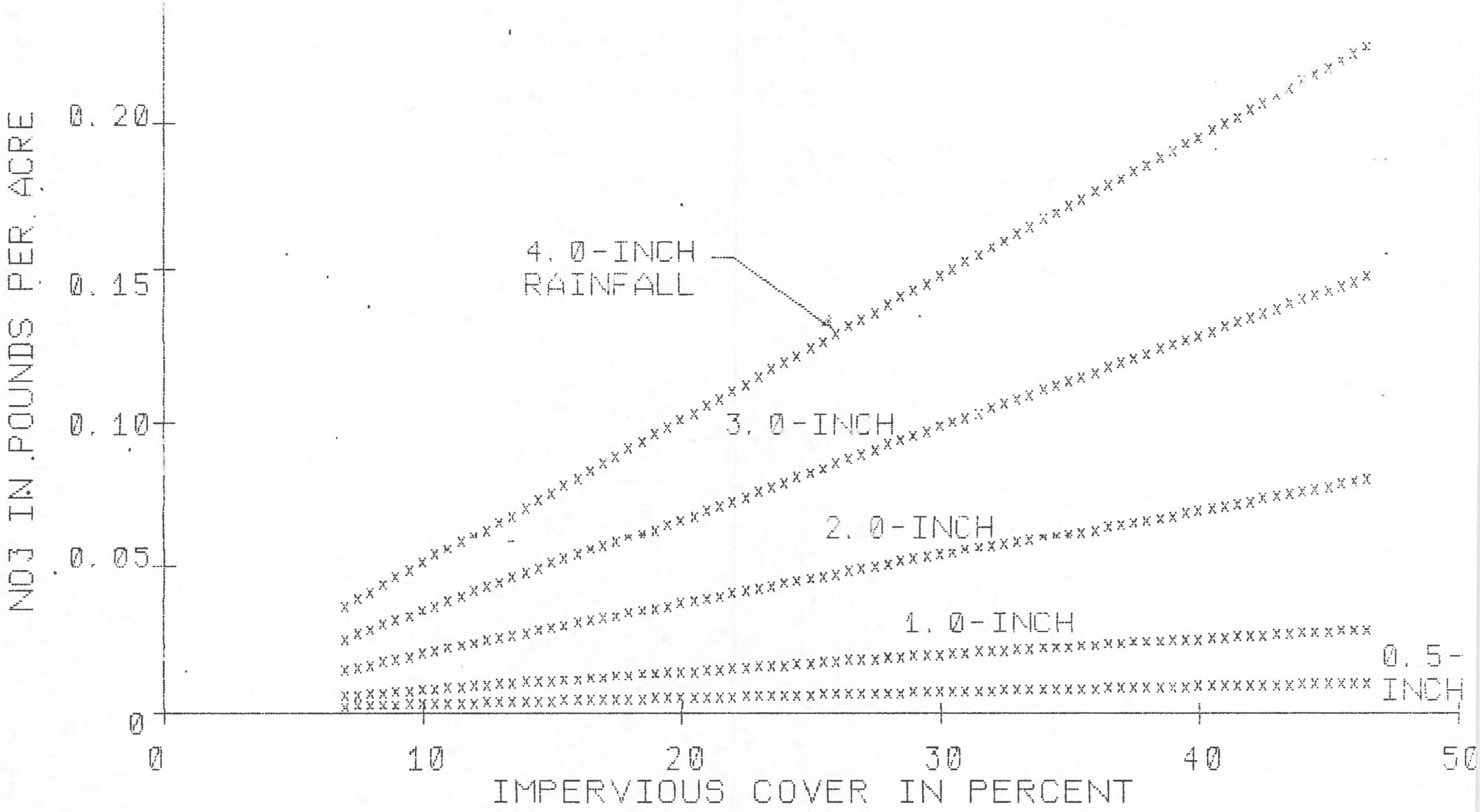


FIGURE 12. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - NO3

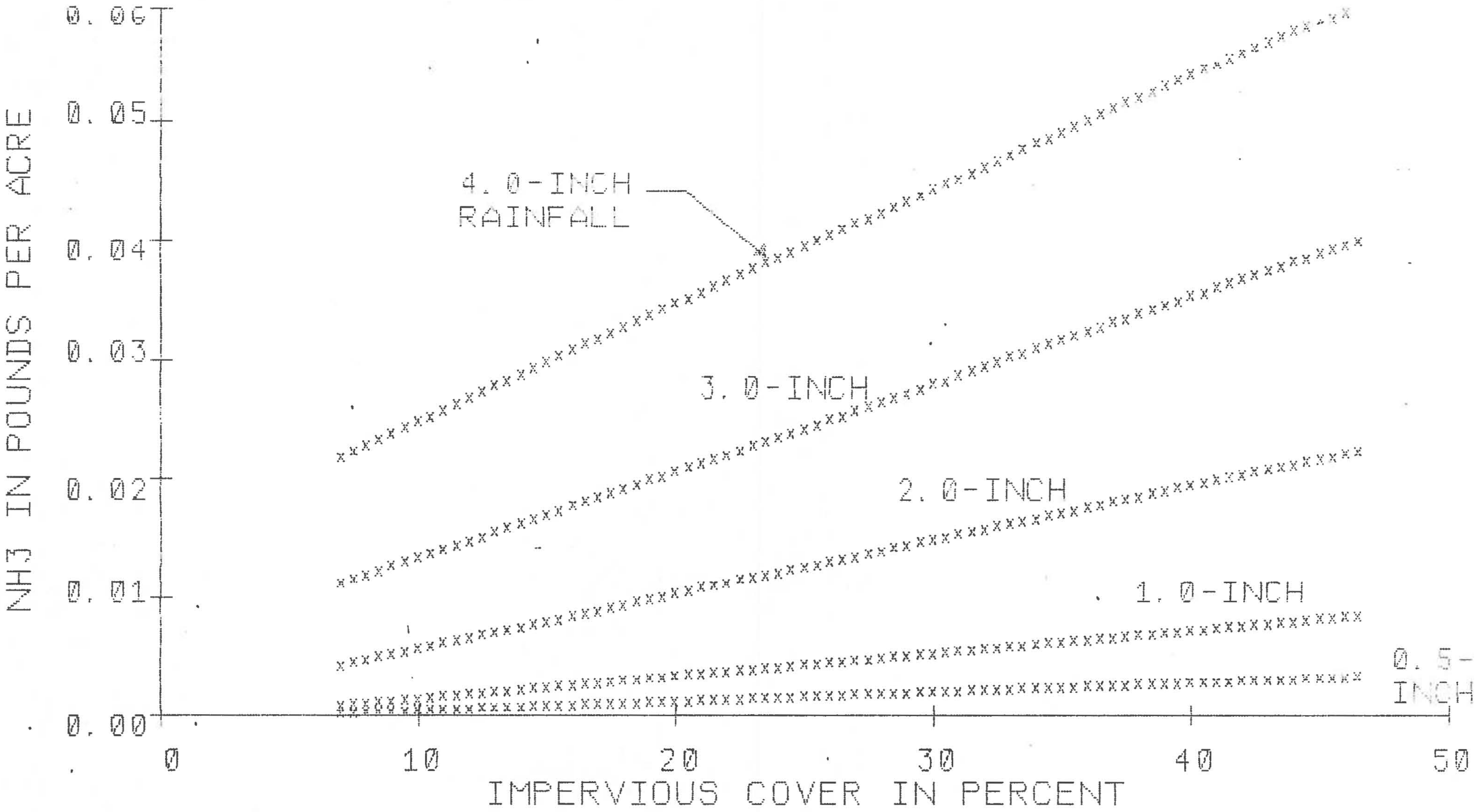


FIGURE 13. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - NH3

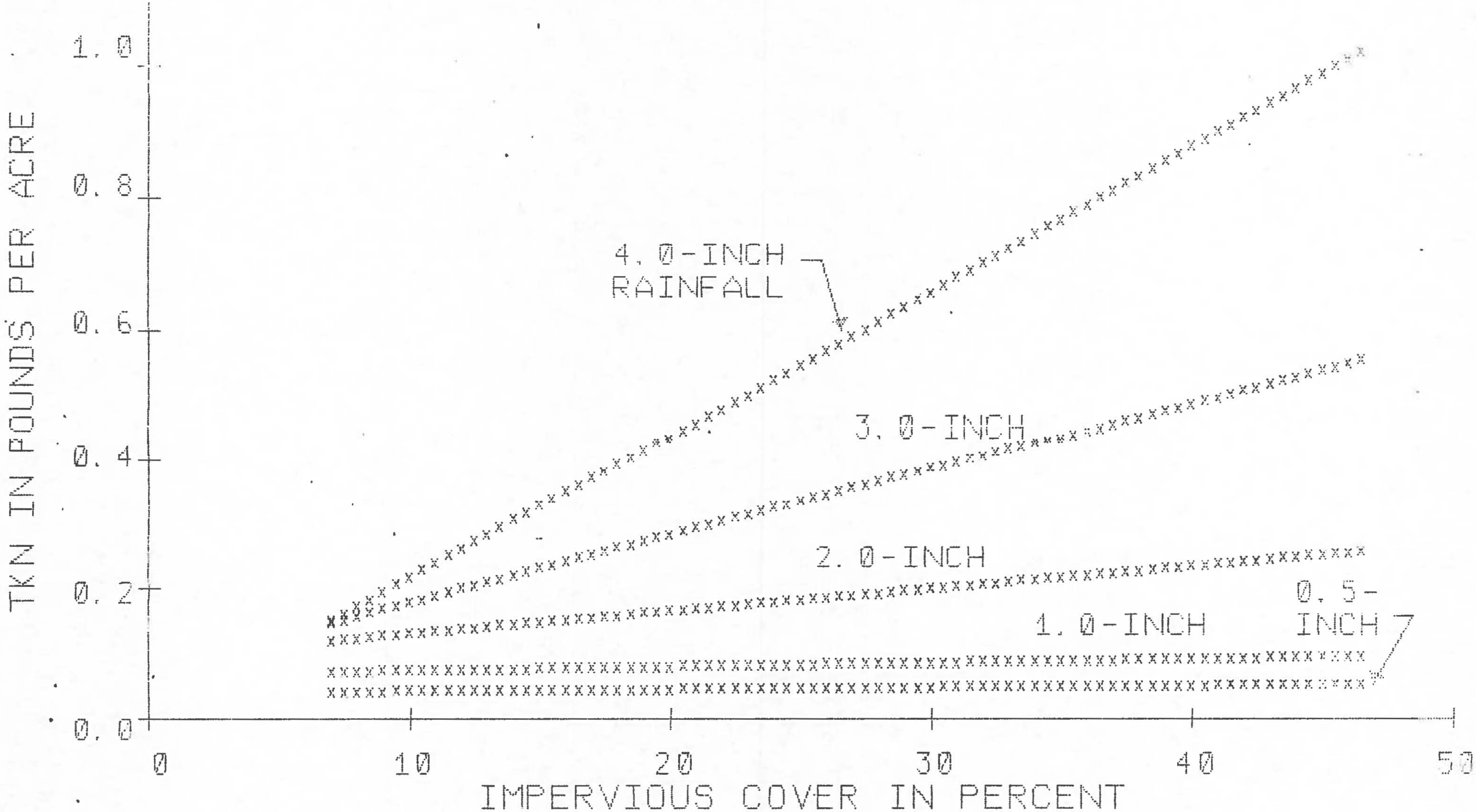


FIGURE 14. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - TKN

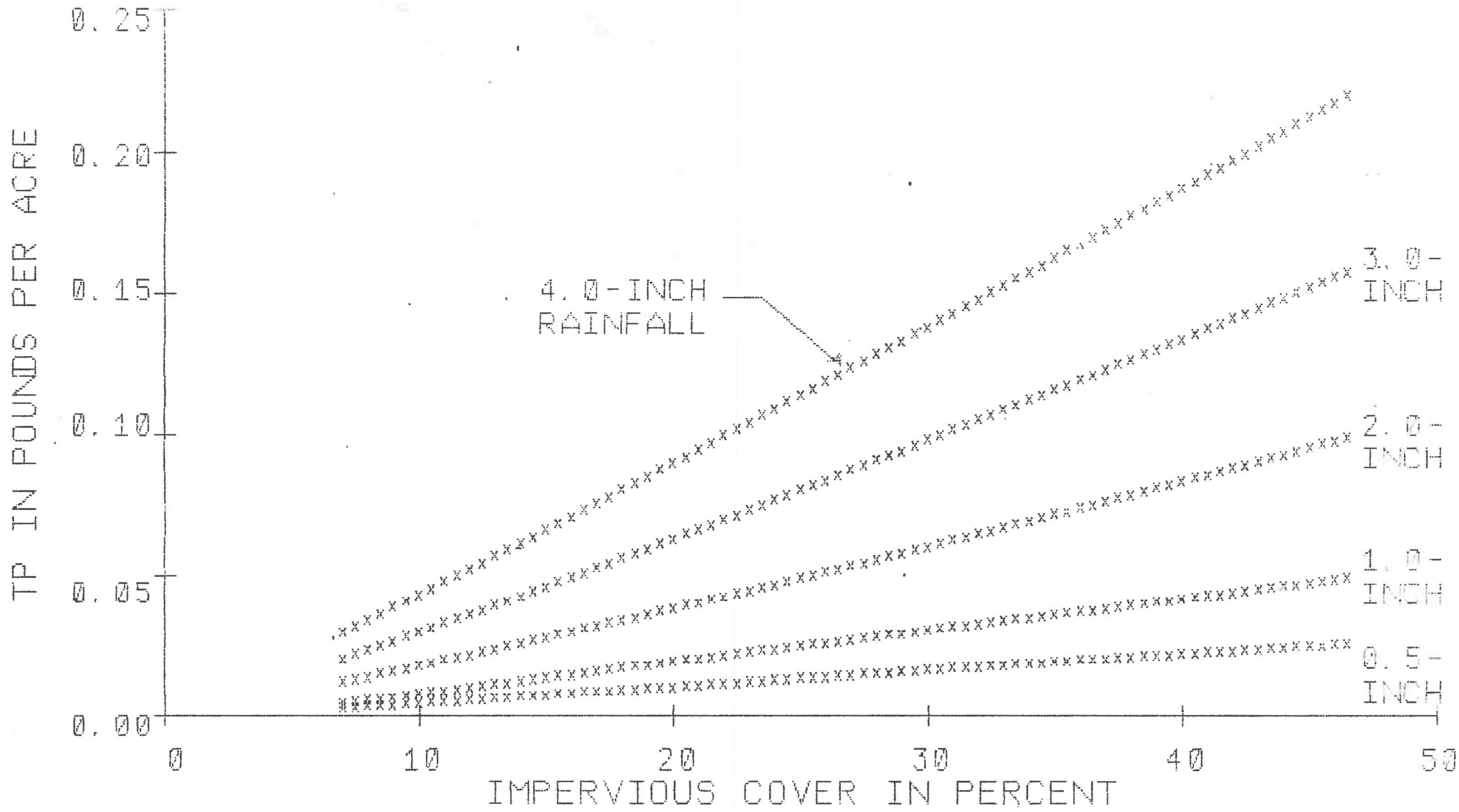


FIGURE 15. RUNOFF POLLUTANT LOADING PER RAINSTORM IN TERMS OF IMPERVIOUSNESS - TP

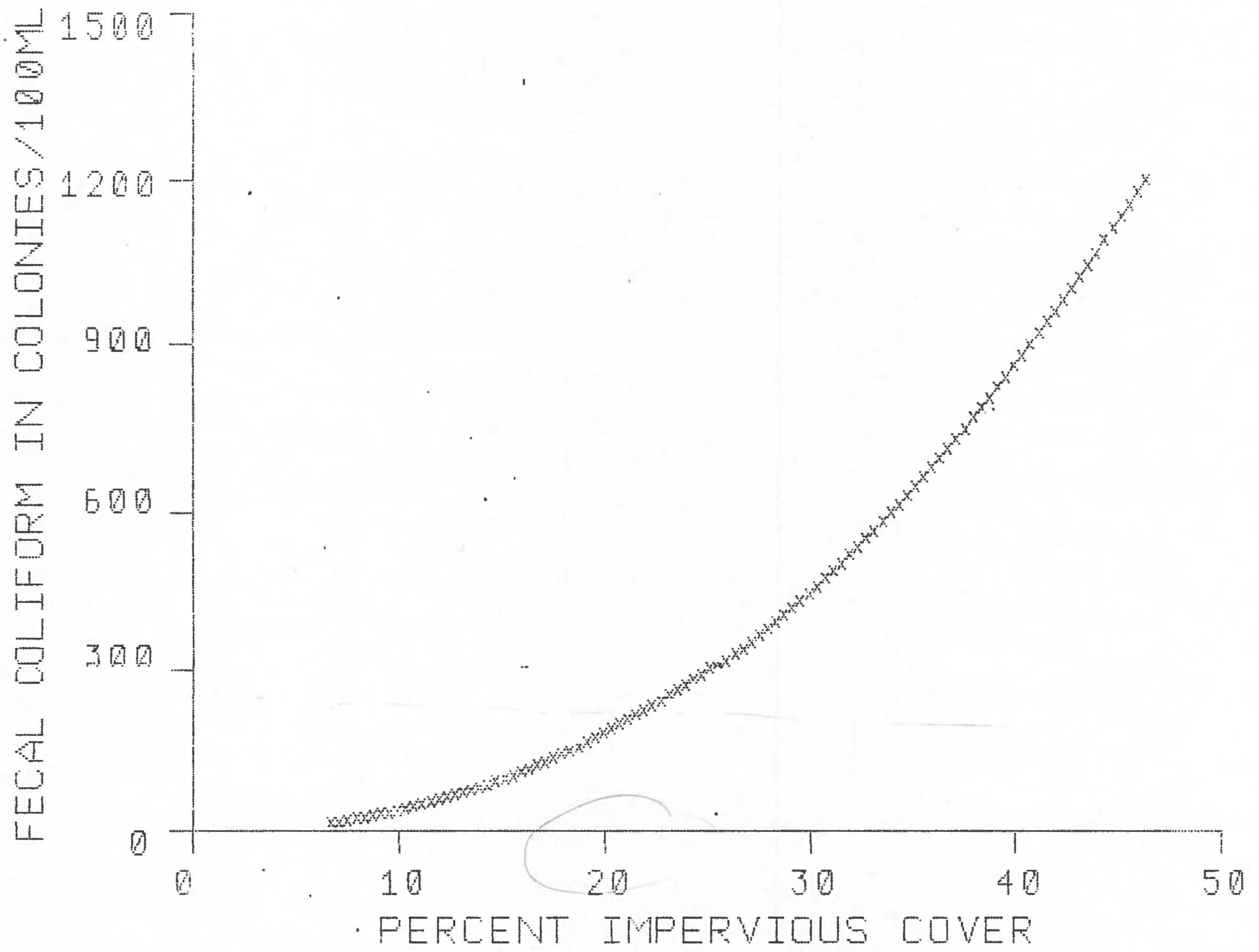


FIGURE 16. BACKGROUND WATER QUALITY CONDITIONS OF AUSTIN CREEKS IN TERMS OF WATERSHED IMPERVIOUSNESS (FECAL COLIFORM)

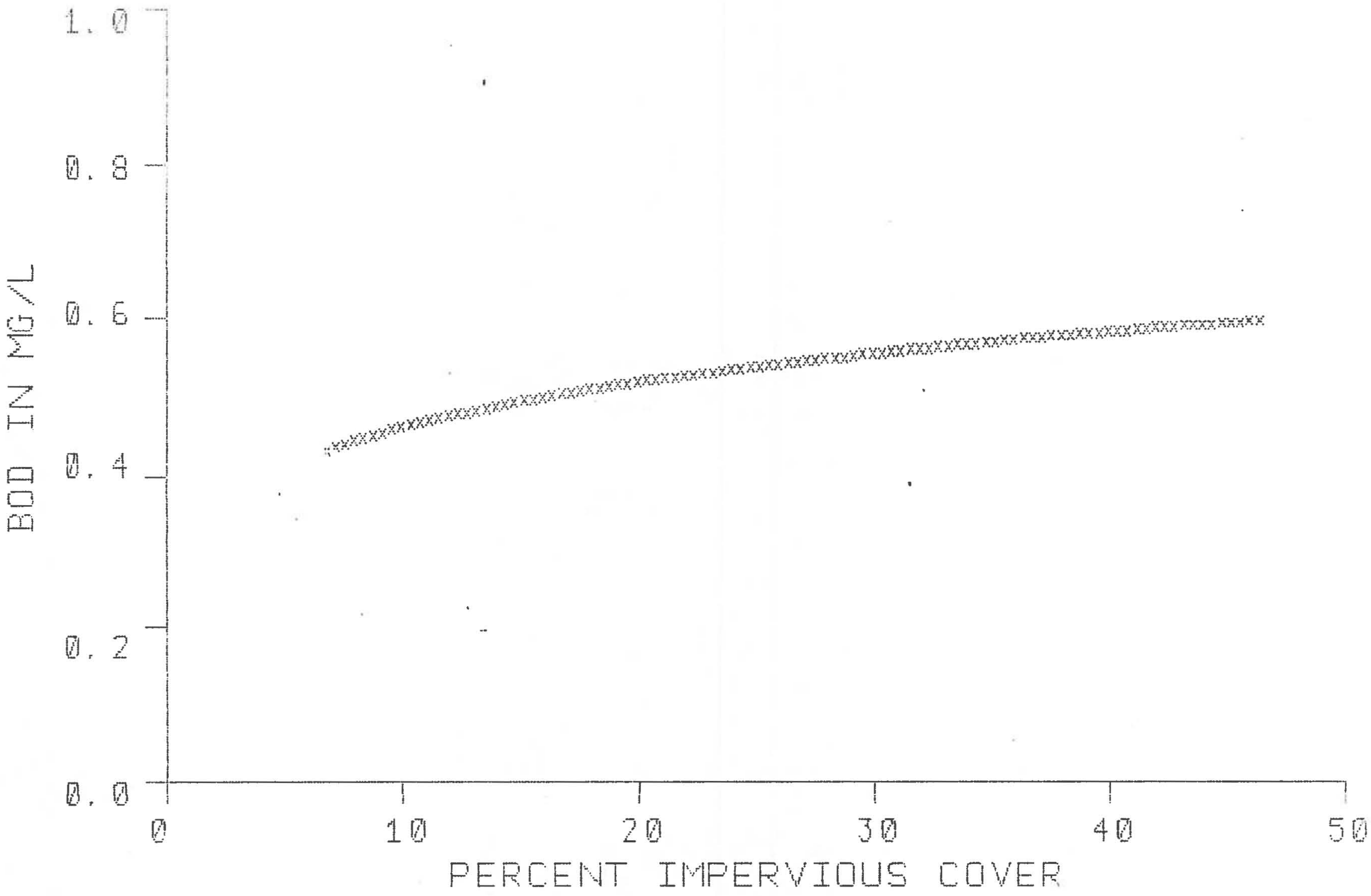


FIGURE 17. BACKGROUND WATER QUALITY CONDITIONS OF AUSTIN CREEKS IN TERMS OF WATERSHED IMPERVIOUSNESS (BOD)

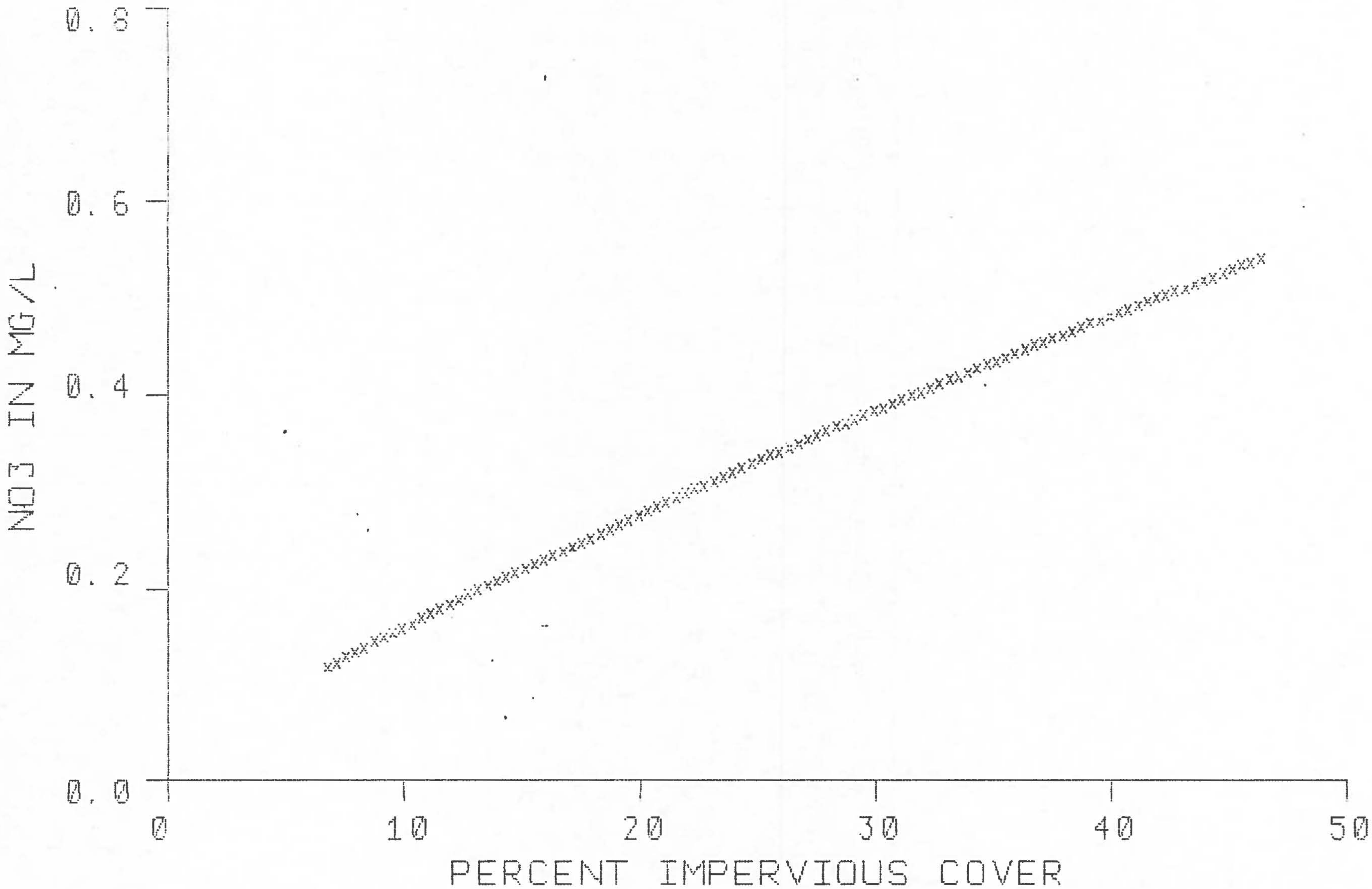


FIGURE 18. BACKGROUND WATER QUALITY CONDITIONS OF AUSTIN CREEKS IN TERMS OF WATERSHED IMPERVIOUSNESS (NO3)

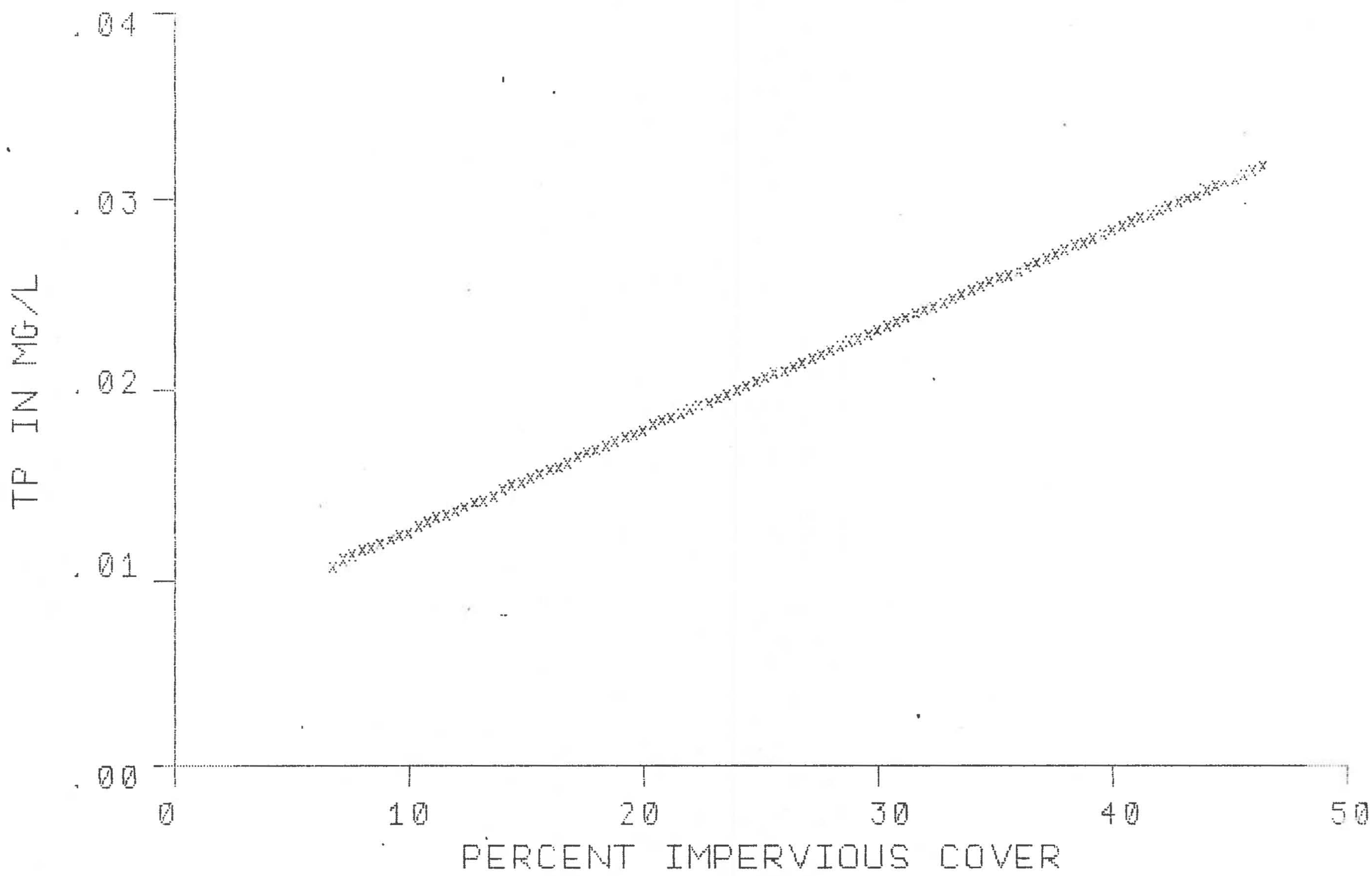
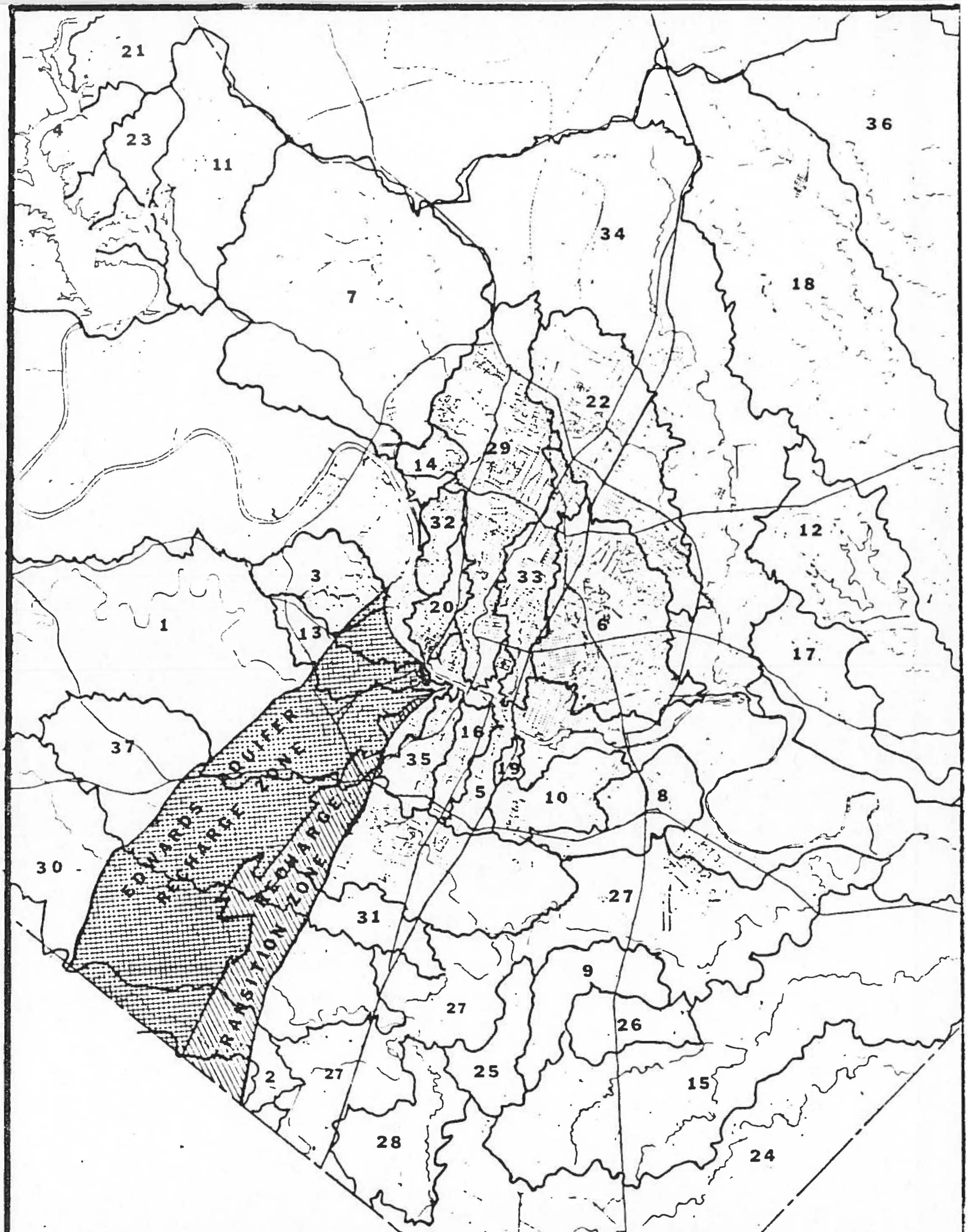


FIGURE 19. BACKGROUND WATER QUALITY CONDITIONS OF AUSTIN CREEKS IN TERMS OF WATERSHED IMPERVIOUSNESS (TP)



AUSTIN WATERSHEDS

Figure 30

1 INCH : 3 MILES

N

AUSTIN WATERSHEDS*

1 BARTON CREEK
2 BEAR CREEK
3 BEE CREEK
4 BIG SANDY CREEK
5 BLUNN CREEK
6 BOGGY CREEK
7 BULL CREEK
8 CARSON CREEK
9 COTTONMOUTH CREEK
10 COUNTRY CLUB CREEK
11 CYPRESS BRANCH
12 DECKER CREEK
13 DRY (DELLANA CREEK)
14 DRY (NORTHWEST) CREEK
15 DRY (SOUTH) CREEK
16 EAST BOULDIN CREEK
17 ELM CREEK
18 GILLELAND CREEK
19 HARPERS BRANCH
20 JOHNSON CREEK
21 LIME CREEK
22 LITTLE WALNUT CREEK
23 LONG HOLLOW
24 MAHA CREEK
25 MARBLE CREEK
26 NORTH FORK
27 ONION CREEK
28 RINARD CREEK
29 SHOAL CREEK
30 SLAUGHTER CREEK
31 SOUTH BOGGY CREEK
32 TAYLORS SLOUGH
33 WALLER CREEK
34 WALNUT CREEK
35 WEST BOULDIN CREEK
36 WILBARGER CREEK
37 WILLIAMSON CREEK

*For Figure 20